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THE ANATOMY AND PATHOLOGY OF THE TEETH.

BY

C. F. W. BÖDECKER, D.D.S., M.D.S.

WITH THREE HUNDRED AND TWENTY-FIVE ILLUSTRATIONS.

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ADOPTED BY THE NATIONAL ASSOCIATION OF DENTAL FACULTIES
AS A TEXT-BOOK FOR DENTAL STUDENTS.

PHILADELPHIA:
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TO HIS
HIGHLY ESTEEMED TEACHER AND FRIEND,

CARL HEITZMANN, M.D.,

THIS BOOK IS DEDICATED BY THE
AUTHOR.

PREFACE.

WHEN, nearly eighteen years ago, I first entered the laboratory of Dr. Carl Heitzmann and listened to his lectures on general histology, I became so thoroughly imbued with the conviction of the correctness of his views that I resolved to study the tissues building up the teeth in the light of the novel doctrine. Ever since I have been a faithful attendant at his laboratory. Besides myself, hundreds of dentists have attended that institution, largely owing to the enthusiastic impulse of my much-lamented friend, the late Dr. William H. Atkinson. As a consequence, a number of these gentlemen, including Professor Frank Abbott, Dr. William H. Atkinson, Dr. John I. Hart, and Dr. F. A. Roy, have enriched dental literature with the results of original investigations, made in the same laboratory, all of which will be found embodied in this book.

So long as the cell-theory holds sway over the minds of the majority of microscopists, the views here laid down cannot meet with general acceptance. As early as 1859 no less a man than Thomas H. Huxley declared that the history of the development of the teeth was not intelligible upon the grounds of the cell-theory. We to-day can state that neither the normal nor the morbid anatomy of the tissues is explicable on the basis of that theory. How long it will be before the novel views advanced by Dr. Carl Heitzmann, and which are directly antagonistic to the cell-theory, will gain a final victory it is impossible to foretell. In our time discoveries are made in rapid succession: some are at once accepted, to be discarded later upon more critical investigation; others, which meet with incredulity or open denial at first, prevail in the long run, as they must do if verified by honest observations and facts. It is gratifying to my highly-esteemed friend and teacher to know that already a number of independent observers have indorsed his views. It is true he has not escaped the criticism, even enmity, which appear to be the lot of every daring original investigator; but while opposition may delay the acknowledgment of these newly-interpreted facts, it will not be able to prevent their ultimate acceptance.

I cheerfully acknowledge the great assistance rendered me by Dr. Carl Heitzmann in the preparation of this book. To him I am indebted not only for the artistic illustrations, which were all made by him, but also for aid in the microscopical researches, both those previously published and those here set forth for the first time.

While the minds of the majority of American dentists are largely directed toward so-called practical topics, I yet hope that no intelligent dental practitioner—and this work has been written only for such—will lay aside the book, after its conscientious perusal, without feeling that he has gained some additional knowledge from it. I ask only unbiased, conscientious reading. I know that our profession is not lacking in students competent and willing to give this, and to them I trust the verdict as to the value of my labors.

This book may help in demonstrating that scientific investigations are not neglected in our country. Its preparation has cost all my leisure time during almost a decade; but if its publication shall prove of service to my profession, I shall feel more than repaid.

CARL F. W. BÖDECKER.

NEW YORK, July, 1894

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THE ANATOMY AND PATHOLOGY OF THE TEETH.

CHAPTER I.

THE SUPERIOR MAXILLARY BONES.

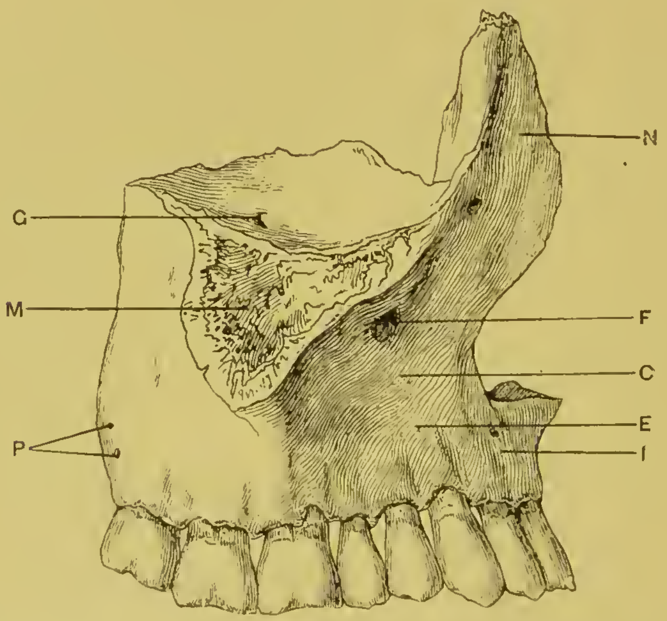
To the dental practitioner these bones, together with the lower jaw-bone, are the most important ones of the human body. They occupy the central region of the face, on either side of the nasal cavities, and each of them, in a normal condition, is mounted with eight teeth. In connection with the other facial and cranial bones, they constitute the frame-work of the upper and greater part of the face. Each superior maxillary contributes to the formation of the roof of the mouth; to the floor and outer walls of the nasal cavities, as well as to the floors of the orbits. Aside from the *body*, which is somewhat cuboidal in shape, we distinguish four processes,—*i.e.*, the *malar*, the *nasal*, the *palatine*, and the *alveolar process*. The body of this bone contains a large cavity, the *antrum of Highmore*, obviously for the purpose of minimizing the weight of the bone, and at the same time of increasing its proportionate strength.

The external or facial surface (Fig. 1) shows above the incisor teeth a slight depression, called the *incisive fossa*. Outward from this is another depression, the *canine fossa*, which is deeper than the incisive, and separated from it by a vertical ridge, the *canine eminence*, corresponding to the socket of the canine or cuspid tooth. At the upper portion of the canine fossa we observe the *infra-orbital foramen*, through which pass the infra-orbital nerve and artery.

The posterior or zygomatic surface is pierced by several apertures, the orifices of the *posterior dental canals*, for the transmission of the posterior dental vessels and nerves. The lower part of the zygomatic surface gradually develops into the *maxillary tuberosity*, which is most conspicuous after the eruption of the wisdom or third molar tooth.

The superior or orbital surface is made up of a thin triangular plate of bone. It is traversed by the *infra-orbital groove*, carrying the infra-orbital nerve and artery. This groove terminates in a canal, dividing into two branches; one of which, the *infra-orbital*, opens below the border of the orbit, while the other, which is smaller, pierces the anterior wall of the antrum, and bears the name of *anterior dental canal*, transmitting the anterior dental vessels and nerve to the front teeth.

FIG. 1.



EXTERNAL OR FACIAL SURFACE OF THE RIGHT SUPERIOR MAXILLARY BONE.

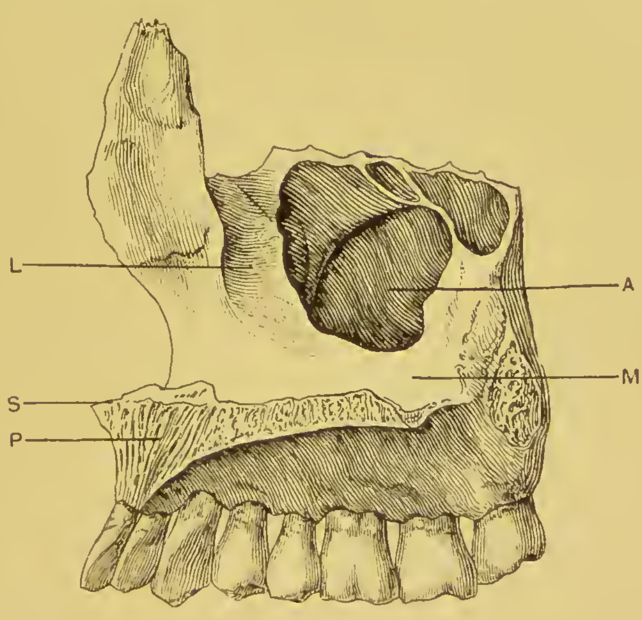
I, Incisive fossa; *C*, canine fossa; *E*, canine eminence; *F*, infra-orbital foramen; *P*, posterior dental canals; *G*, infra-orbital groove; *M*, malar process.

The *malar process* is a prominent rough eminence serving for the articulation with the malar bone. The descending ridge constitutes the boundary between the facial and zygomatic surfaces. From this ridge a small portion of the masseter muscle takes its origin.

The *nasal process*, directed upward, has a concave external surface. The anterior border of this process articulates with the nasal bones; the posterior is hollowed out by a groove in which the lachrymal duct lodges. This groove is converted into a canal by the lachrymal and a part of the inferior turbinated bones.

The *palate process* (see Fig. 2) is a strong piece of bone projecting horizontally from the inner surface of the superior maxilla. It is especially thick anteriorly, the upper surface forming a large portion of the floor of the nasal cavity, while the lower surface makes up the greater portion of the roof of the oral cavity. The lower surface is slightly concave, and is channeled at the posterior part of its alveolar border for the passage of the posterior palatine vessels and the anterior and external palatine nerves. The two palate processes assist in forming an orifice in the median line, the *anterior palatine canal.* This canal is divided into four compartments, two of which run laterally to the right and left nasal fossæ, while the anterior and posterior compartments run along the median line. The anterior one serves for the transmission of the anterior branch of the descending palatine arteries. The anterior and the posterior compartments transmit the naso-palatine nerves, the left running through the anterior, the right through the posterior canals. The roof of the mouth is pierced by a number of small canals which

Fig. 2.

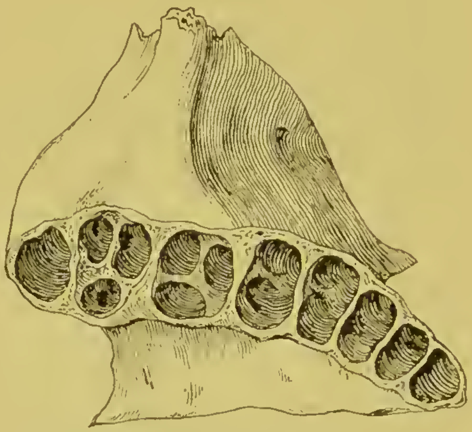


Inferior Surface of the Right Superior Maxillary Bone.

P, palate process; *S*, anterior nasal spine; *A*, opening of antrum; *M*, lower meatus of nasal cavity; *L*, lachrymal groove.

carry the vessels for the nutrition of the bone. The upper surface of the palate process is concave and smooth, exhibiting the openings of the canals above mentioned. The inner border of the palate process is raised into a central ridge which supplies a space of attachment to the vomer. Anteriorly, this process produces a sharp prolongation, the *anterior nasal spine.* The posterior border serves for articulation with the palate bone. The upper portion of this surface shows a large, irregular opening, that of the antrum. The upper border of the opening is partially closed by the cellular cavities of the ethmoid bone. Below this opening a smooth concave surface presents itself, the *lower meatus of the nasal cavity.* Behind the opening we notice a rough surface that articulates with the perpendicular

FIG. 3.



THE ALVEOLAR PROCESS OF THE RIGHT SUPERIOR MAXILLARY BONE. VIEW FROM BELOW IN NATURAL SIZE.

plate of the palate bone, being traversed by a groove which, with a corresponding portion of the adjacent palate bone, forms the *posterior palatine canal*, directed obliquely downward and forward. In front of the opening of the antrum a groove is seen, which with the lachrymal and inferior turbinated bones constitutes the *lachrymal* or *nasal duct.* At the base of the nasal process is the *horizontal* or *inferior turbinated crest* for the articulation of this process with the inferior turbinated bone. The wall of the inferior meatus of the nasal cavity is perforated by numerous small foramina, which serve as carriers of nutrient vessels.

The *alveolar process* is the portion of the jaw which holds the teeth. It contains eight excavations or sockets for this purpose (Fig. 3). The deepest of these excavations is the socket of the canine or cuspid tooth; the sockets of the molars are the widest, and are usually subdivided into three smaller cavities, corresponding in number with the roots of the teeth. The socket of the third molar is usually single, while that of the first bicuspid exhibits two cavities, and that of the second bicuspid usually but one. The sockets for the incisors are always single. They are of roundish form for the central, but for the lateral incisors the sides of the receptacles are somewhat compressed.

The *antrum* is the largest of the so-called pneumatic spaces of the skull. It is a cavity of four surfaces,—the *upper* or *orbital* surface; the *posterior* surface, produced by the maxillary tuberosity; the *anterior* or *facial* surface, which is slightly depressed by the canine fossa; and the *inner* or *nasal* surface. When regularly formed, the antrum has the shape of a triangular pyramid, and either the upper orbital or the inner nasal surface may be considered the base of the pyramid. The inner wall of the antrum is divided by the articulation of the turbinated bone into an upper and a lower half (*pars supra-* and *pars infra-turbinalis*). The lower half is made up anteriorly by the superior maxillary, and posteriorly by the vertical lamella of the palate bone. The upper half is supplied with several openings, which are quite large in the skeleton, but much smaller in the vital state, in which condition the bones are covered by their lining membrane. If the mucous covering closes these gaps, such membranous portions Zuckerkandl* terms *fontanelles.* Of these, he designates one as anterior and one as posterior. There is left only a longitudinal opening, the ostium maxillare, within the unciform process of the ethmoid bone, and one ethmoidal cell, invested by a mucous membrane, communicating with the frontal sinus and the nasal cavity. The lower surface or floor of the antrum is formed by a thin bony plate. Between this and the alveoli of the teeth is a layer of spongy bone. The latter substance, as a rule, is thinnest over the roots of the molar teeth. The roots of the incisor teeth are not within the boundary of the antrum. The canine and the first bicuspid, though near the floor of the antrum, do not quite reach it, the floor being overlaid by a bulky osseous structure. The apices of the roots of the second bicuspid and the buccal roots of the molars are in contact with the floor of the antrum. The second bicuspid and the first molar, as a rule, correspond to the deepest portion of the antrum.

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* Normale und Pathologische Anatomie der Nasenhöle. Wien, 1882.

Variations in the Size of Antra.—The difference in size of the upper jaws of various individuals is not great, but of the antra the shapes and sizes vary considerably; nay, sometimes there are marked differences in the two antra of the same head.

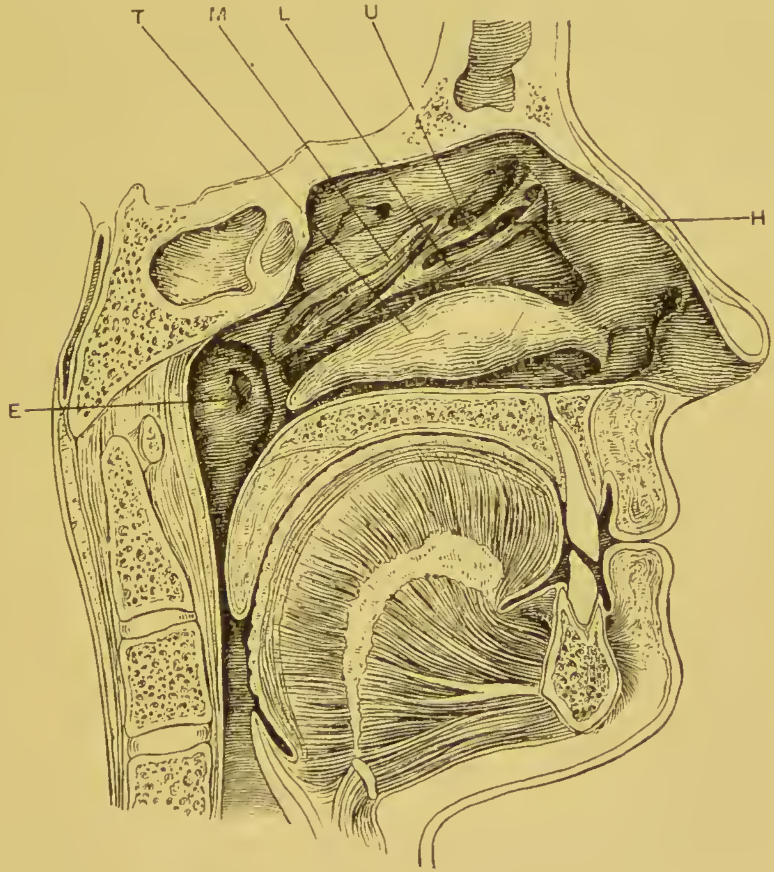
Zuckerkandl publishes the following table of variations in the size of antra, some of the figures of this table being quoted from C. Reschreiters:

Heights of Upper Jaws.	Heights	Breadths	Depths
	of Antra given in Millimeters.		
64	19	25	21
64	29	25	21
64	32	28	33
64	32	25	34
64	32	24	32
64	33	22	34
64	39	25	30
55	13	15	14
59	37	29	18

Communication between the Antrum and the Nasal Cavity.—The opening termed *ostium maxillare* is situated in the middle meatus of the nose. It leads into the *hiatus semilunaris* in company with the *ostium frontale*, which communicates with the frontal sinus (see Fig. 4). The latter is situated superficially in the frontal portion, while the ostium maxillare lodges backward and is somewhat hidden in the *infundibulum.* The best view of the ostium maxillare is obtained from the antrum (see Fig. 5, *M*), where we observe it a little below the orbital surface, on the upper border of the nasal surface of the antrum. Its shape is irregular, most frequently semilunar, but often oval, and sometimes round. According to Zuckerkandl, this opening varies from three to nineteen millimeters in length, and from three to five millimeters in breadth. Sometimes there exists, between the antrum and the nose, an accessory communication, which is usually small and round (see Fig. 5, *A*). This accessory opening generally is situated in the posterior fontanelle, somewhat lower than the ostium maxillare. In rare instances the communication between the antrum and the nasal cavity is closed, the result either of a chronic inflammatory process or of a malformation during development.

The Lining Membrane of the Antrum has a double function,—*i.e.*, it serves as a periosteal cover, supplying the nutritive vessels to the bony walls of the cavity, and at the same time secretes mucus. It is continuous with the mucous lining of the nasal cavity, and is closely adapted to the depressions and elevations in the bony wall of this cavity. According to Sappey, the mucosa of the antrum is supplied with glands, which in appearance are much like the Meibomian glands of the eyelids. They are irregularly distributed, and much scantier than those of other mucous membranes.

FIG. 4.



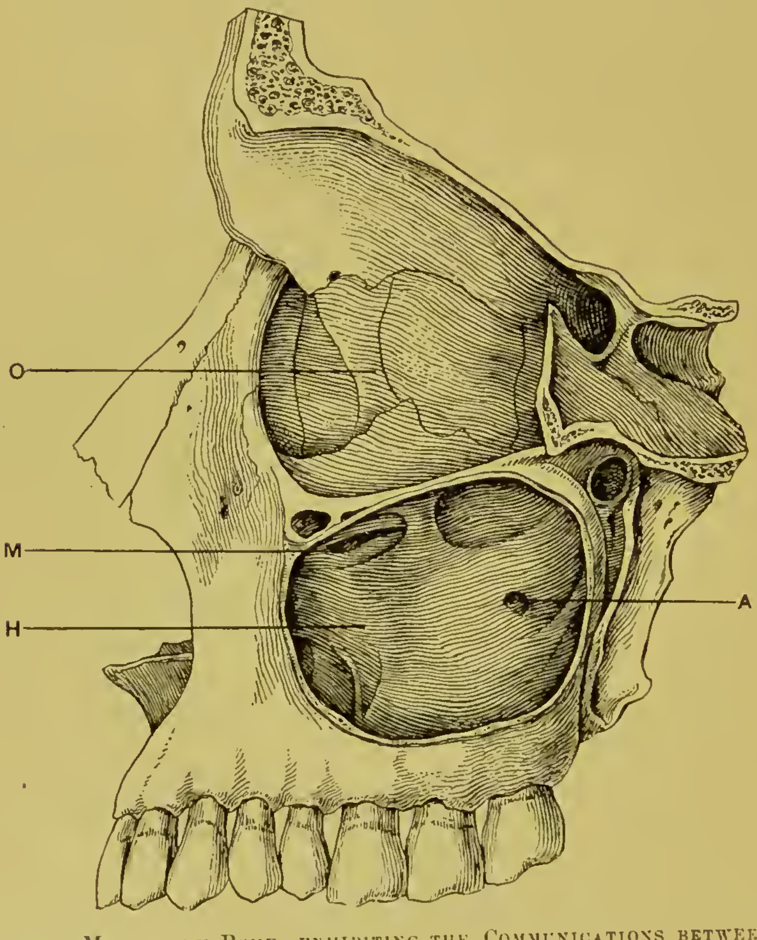
SAGITTAL SECTION THROUGH THE NASAL AND ORAL CAVITIES, PARTLY AFTER ZUCKERKANDL.

H, semilunar hiatus; *U*, upper lip, the ethmoidal bulla; *L*, lower lip, the unciform process; *M*, insertion of middle turbinated bone; *T*, lower turbinated bone; *E*, mouth of Eustachian tube.

The antrum is supplied with blood-vessels, principally derived from the mucous membrane of the nasal cavity, although some of the smaller branches arise from the posterior dental arteries through the alveoli.

Development.—The superior maxilla is one of the earliest bony formations, and, as anatomists suppose, it starts from four centers of calcification, namely: the *premaxillary*, the *palatine*, the *maxillary*, and the *malar* portions. With the exception of the maxillary portion, all these develop from and around hyaline cartilage. The premaxilla, to the presence of which the great German philosopher and poet, Goethe, first drew attention, holds the two incisor teeth on each side. In young subjects its articulation with the palatine portion is still visible. In the congenital malformation of the upper jaw termed *cleft palate*, this portion is separated from the remainder of the maxillary bone by a single or double fissure, usually associated with a corresponding fissure of the upper lip, called *hare-lip*.

FIG. 5.



LEFT SUPERIOR MAXILLARY BONE, EXHIBITING THE COMMUNICATIONS BETWEEN ANTRUM AND NASAL CAVITY. (AFTER ZUCKERKANDL.)

O, orbital cavity; *H*, maxillary cavity or antrum of Highmore; *M*, slit-like opening or ostium maxillare; *A*, accessory opening between antrum and nasal cavity.

The antrum begins to develop in the maxillary portion of the bone at about the fourth month of fœtal life.

Involution.*—By this term is indicated a retrograde change leading to a partial or complete disappearance of tissues and organs. It is of frequent occurrence in embryonal development, the same as in senile reduction of the size of organs, especially that of the skeleton, whereby bone-tissue is brought back to fibrous and myxomatous tissue preceding absorption.

The studies of the authors herein named were made on the upper jaw of a woman who died when seventy-five years of age. The thickness of this jaw, between the oral and the nasal cavities, was not more than from four to five millimeters. The surface of the oral cavity was perfectly smooth, without a trace of a tooth or socket. The bone was present only in thin ledges, arranged in an irregular line, and without distinction between the compact and the cancellous structures. Numerous pieces of hyaline cartilage were present in the same stratum with the bony tissue, which proves that the cartilage grows from a previous bony structure, and that it replaces the latter.

CHAPTER II.

THE INFERIOR MAXILLARY BONE.

THIS is the largest bone, and the only movable one, of all the facial bones. It consists of a *horizontal body* and *two perpendicular projections*, the *rami*, arising from the body nearly at right angles to it.

The body presents for examination two surfaces, the *external* and the *internal;* and two borders, the *alveolar* and the *inferior.* The external surface (see Fig. 6) is convex from the median line to the ramus, and slightly concave from above downward. In the middle line we observe a shallow *vertical ridge*, indicative of the junction of the two pieces of bone from which the body develops. The ridge terminates below in a protrusion termed the *mental process.* Outward of this central ridge is a slight depression, the *incisive fossa.* Farther backward we find the large

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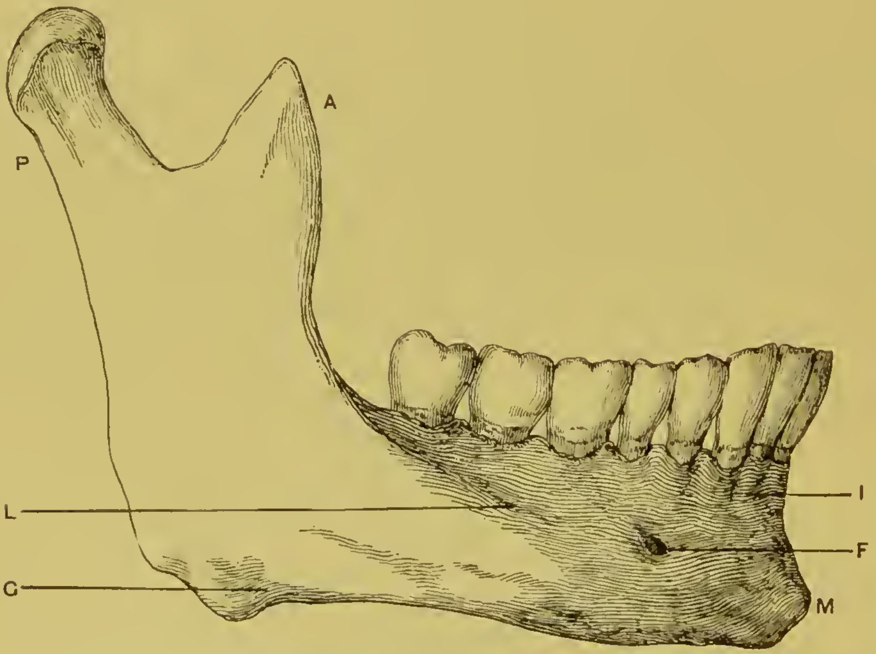
* "Senile Atrophy of the Upper Jaw." By Carl Heitzmann and Frank Abbott. *Dental Cosmos*, 1892.

mental foramen for the transmission of the mental nerve and artery. The location of this foramen corresponds with the interstice between the roots of the first and second bicuspid teeth. Posterior to this foramen begins a curved ridge, the *external oblique line*, which runs backward and upward, being continuous with the anterior border of the ramus.

The alveolar process is more massive posteriorly than in its anterior portion. It is pierced by sixteen sockets for the reception of the teeth.

The inferior border of the body is rounded and quite massive anteriorly; posteriorly it becomes more narrow. In the vicinity of the rami this border exhibits a *shallow groove*, in which the facial artery is located.

Fig. 6.



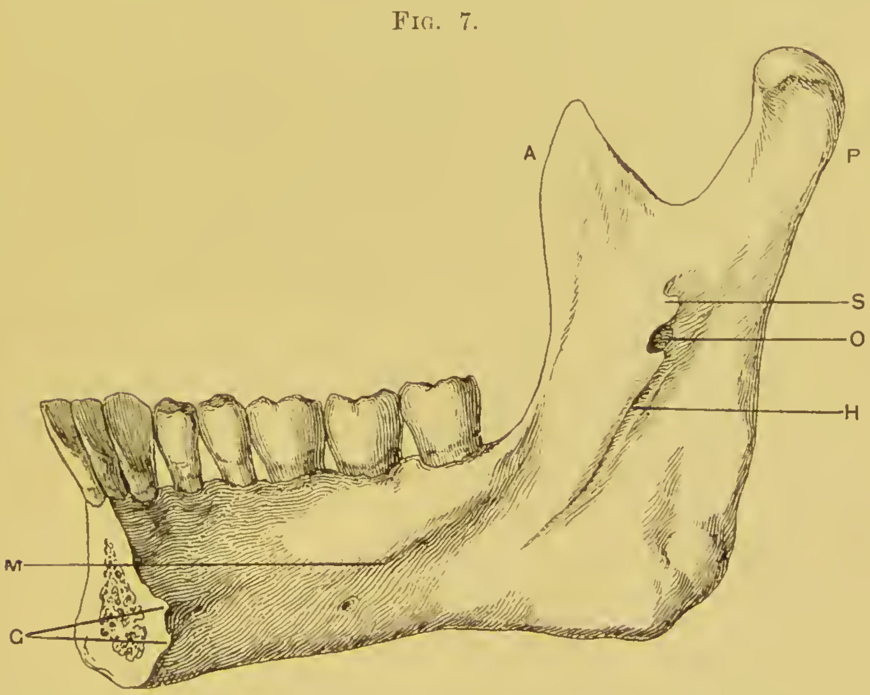
The Inferior Maxillary Bone—External Surface of the Right Side.

M, mental process; *I*, incisive fossa; *F*, mental foramen; *L*, external oblique line; *G*, groove for facial artery; *A*, anterior or coronoid process; *P*, posterior or condyloid process.

The internal surface of the body is markedly concave from the median line to the ramus, and slightly convex from above downward. (See Fig. 7.) In the central line we observe four tubercles, two above and two below, the *genial tubercles*, which vary greatly in size and arrangement in different individuals. Laterally to the tubercles we notice a shallow depression, the *sublingual fossa*, in which the sublingual gland rests. Posterior to this depression is the beginning of the *internal oblique line* or *mylo-hyoid ridge*, which becomes more distinct as it passes upward and backward. The portion above this line is smooth and covered by the oral mucous membrane, whereas the portion below shows a shallow depression, the *submaxillary fossa*, corresponding to the site of the submaxillary gland.

The perpendicular projections, or *rami*, have a more or less quadrilateral shape, each ramus presenting two surfaces, four borders, and two offshoots. The external surface is ridged, and serves for the attachment of the masseter muscle. The internal surface is pierced about its center by an oblique aperture, the opening of the *inferior dental canal*. Anteriorly this aperture is surmounted by a ridge terminating in a *sharp spine*, which at its lower part shows a notch leading to the *mylo-hyoid groove*, for the mylo-hyoid vessels and nerve. The lower border of the ramus exhibits a large rough surface for the attachment of the internal pterygoid muscles.

Fig. 7.



The Inferior Maxillary Bone—Internal Surface of the Right Side.

G, genial tubercles; *M*, mylo-hyoid ridge; *O*, opening of the inferior dental canal; *H*, mylo-hyoid groove; *A*, anterior or coronoid process; *P*, posterior or condyloid process.

The *inferior dental canal* takes an oblique course downward and forward in the ramus, and a horizontal one in the body. This canal is located underneath the sockets of the teeth, with which it communicates by small openings. At a point about level with the first bicuspid tooth it ends in the mental foramen. In the posterior two-thirds of the bone the inferior dental canal runs near the internal surface, while in the anterior third it is near the external surface. This canal holds the inferior dental vessels and nerve, from which small branches pass to the apices of the roots of the teeth through the small openings at the bases of the alveoli referred to above.

The upper border of the ramus is thin, and shows two processes, the *anterior* or *coronoid,* and the *posterior* or *condyloid.* Situated between these processes is a deep depression, the *sigmoid notch.* The coronoid process is a thin piece of bone serving mainly for the attachment of the temporal muscle, and—at its outer surface—for the attachment of the masseter muscle. The condyloid process is more massive than the coronoid, and terminates in the condyle, which is covered with hyaline cartilage. The condyle, placed upon a constricted portion of the neck, is of an oblong shape. Its long axis is set obliquely upon the neck, the outer extremity being higher and directed more forward than the inner. Its surface is convex both antero-posteriorly and from side to side.

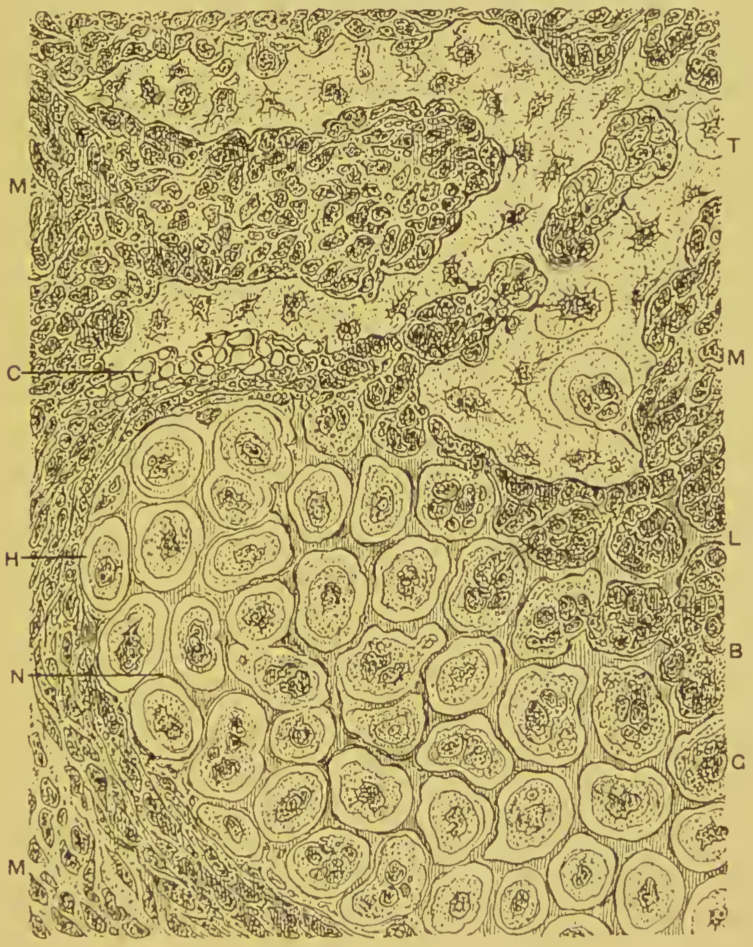
The lower border of the ramus is thick and continuous with the body of the bone. At the angle of the jaw it is marked by oblique ridges on each side, for the attachment of the masseter and internal pterygoid muscles.

The posterior border of the ramus is covered by the parotid gland.

Development and Involution.—The lower jaw, one of the first-formed bones of the embryo, is developed principally from a hyaline cartilage, which, in honor to its discoverer, is termed *Meckel's cartilage.* The formation of osseous tissue begins about the sixth week of intra-uterine life. (See Fig. 8.)

Meckel's cartilage, invested by perichondrium,—which at this stage is not as yet fibrous, but made up of spindle-shaped protoplasmic bodies,—forms a ledge, from and around which ossification takes place. The perichondrium plays as great a part in the production of bone-tissue as the cartilage itself. The first step toward the development of bone is the calcification of the basis-substance around the cartilage-corpuscles. Next a reappearance of protoplasm takes place in the non-calcified portion of the basis-substance, whereby the entire territory of the cartilage-corpuscle is rendered granular. An increase in the size of the granules results in an augmentation of the nuclei, and at last the entire cartilage-corpuscle is transformed into a cluster of medullary or embryonal corpuscles, which furnish the material for bone-production. A preliminary stage of ossification is a deposition of lime-salts in a number of embryonal corpuscles, derived either from the hyaline cartilage or the perichondrium. By the coalescence of a number of such bodies territories of globular shape are formed, the center of the globules being

Fig. 8.



First Formed Trabeculæ of Bone, in Lower Jaw of Human Embryo, Six Weeks Old.

H, hyaline, or primordial, or Meckel's cartilage; *N*, non-calcified basis-substance around the territories of hyaline cartilage; *L*, calcified basis-substance of territories of cartilage-corpuscles; *B*, cartilage broken up to embryonal or medullary corpuscles; *G*, coarsely granular cartilage-corpuscles; *C*, calcified embryonal corpuscles; *T*, trabeculæ of bone-tissue with territories; *M*, *M*, *M*, myxomatous or medullary connective tissue. Magnified 200 diameters.

occupied by bone-corpuscles, while the peripheral portion is transformed into glue-yielding basis-substance, saturated with lime-salts. This change does not alter the structure of the protoplasm. The trabeculæ of bone are originally small and irregular; later they unite into cancellous tissue, inclosing medullary spaces filled with protoplasmic bodies and carrying blood-vessels.

Fig. 9.

Inferior Maxilla of an Embryo in the Second Half of the Third Month.

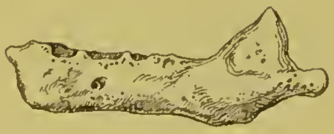
In the second half of the third month the maxilla is as yet a minute ledge of bone, but with indications of future sockets, and of the coronoid and condyloid processes. (See Fig. 9.)

In the first half of the seventh month the future sockets of the teeth are wide and irregular excavations. Both the coronoid and condyloid processes are plainly seen, the latter being almost horizontal. The mental foramen is already established. (See Fig. 10.)

At the time of birth the lower jaw is made up of two pieces, articulating in the center line. The upper border of these pieces is grooved, without being subdivided into sockets. The cortical portion is imperfect and pierced by numerous medullary spaces, especially near the central symphysis and in the region of the rami. The coronoid is more advanced in size than the condyloid, which latter retains a nearly horizontal position. (See Fig. 11.)

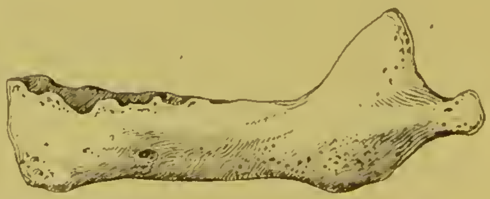
In the sixth year of life the inferior maxillary bone has attained a considerable size, and the condyloid process is inserted at an obtuse angle. Of the teeth we observe on either side of the jaw the two temporary incisors, the cuspid, and three molars,—two temporary and one (the sixth-year) permanent. (See Fig. 12.) In the adult the condyloid process is conspicuous by its almost rectangular junction with the ramus, whereas with advancing age this process appears inserted again at an obtuse angle.

Fig. 10.



Inferior Maxilla of a Fœtus in the First Half of the Seventh Month.

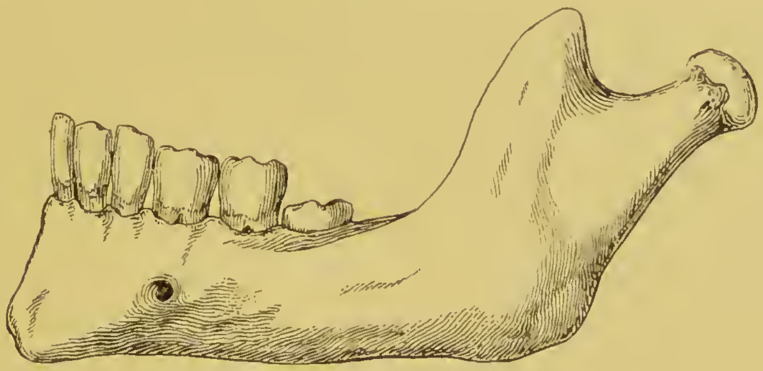
Fig. 11.



Inferior Maxilla at the Time of Birth.

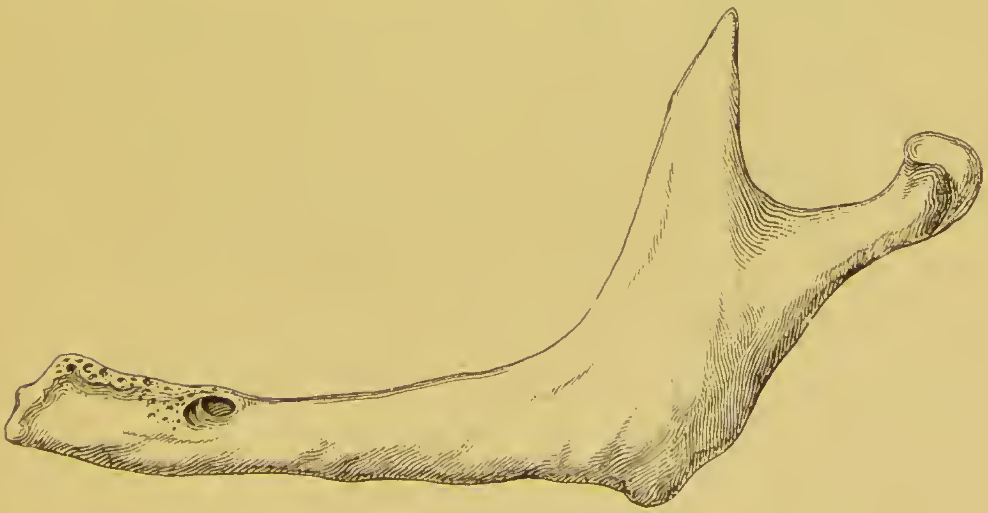
In old age the lower jaw gradually returns to its embryonal shape. (See Fig. 13.) After the teeth are lost, the sockets become obliterated, and are replaced by small pits and grooves, the points at which the conversion of the bone into medullary tissue begins. The mental foramen is now seen to be near the previous alveolar surface, and to be considerably widened. The body, as well as the ramus, is reduced to a thin ledge of bone, mostly smooth at the surface. The laws of development, as well as of senile involution, are not as yet fully understood. It is certain, however, that all changes take place by juxtaposition, and not by interstitial growth. All phenomena become intelligible, if we admit the fact that not only are the bone-corpuscles endowed with properties of life, but so also is the basis-substance, and thus both are enabled to be reconverted into protoplasm, and again to give rise to connective tissue.

FIG. 12.



INFERIOR MAXILLA OF A BOY SIX YEARS OLD.

FIG. 13.



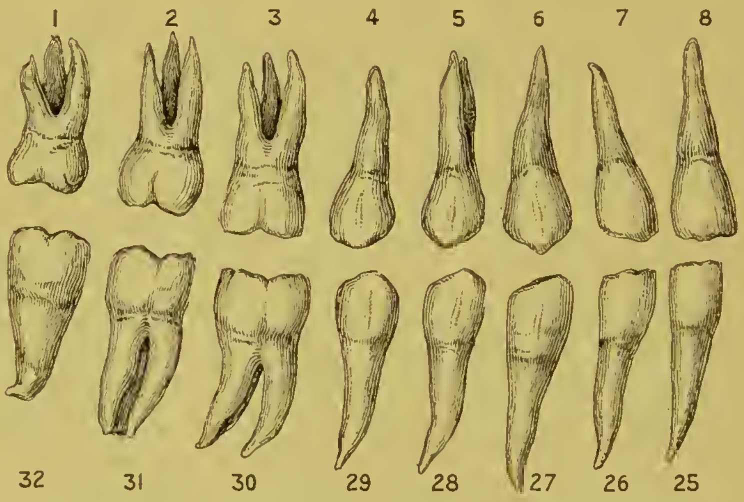
INFERIOR MAXILLA IN SENILE AGE.

CHAPTER III.

THE TEETH.

THE tooth, macroscopically considered, consists of a crown, a neck, and a root. The crown of a tooth is that portion which is covered with enamel, and, when the tooth is fully erupted, is exposed above the margin of the gum. The neck is the part that is covered by the gum. It begins at the border of the enamel and extends to the alveolar process. The root, in its normal condition, is entirely inclosed by the alveolar process.

FIG. 14.



THE RIGHT TEETH OF AN ADULT TWENTY-TWO YEARS OLD. EXTERNAL VIEW. LABIAL (BUCCAL) SURFACES.*

Between the neck and the root of a tooth we observe no distinct macroscopical boundary, but for descriptive purposes and for practical convenience we employ differentiating terms.

The dental formula that represents the permanent teeth of the human mouth is noted as follows:

$$I\,\tfrac{2}{2}:\ C\,\tfrac{1}{1};\ B\,\tfrac{2}{2}:\ M\,\tfrac{3}{3} = 32$$

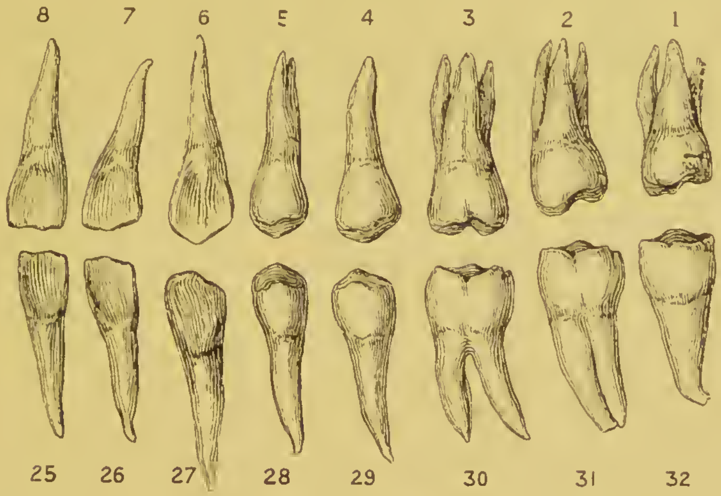
(See Figs. 14 and 15.)

---

*The teeth Nos. 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, and 24, in shape correspond with their fellows of the opposite side of the dental arch, except that the general shape of their crowns is reversed, and it has therefore been deemed unnecessary to illustrate them.

Upon examining the crown of a tooth, we observe on it five surfaces. First, the outer surface in regard to all teeth, called the "labial" surface of the front teeth, and the "buccal" surface of the bicuspids and molars. Second, the inner surface, in contact with the tongue, and therefore called "lingual." Third, the "grinding-surfaces" and the "cutting-edges," the former name being applied to the under surfaces of the upper bicuspids and molars and the corresponding grinding-surfaces of the lower bicuspids and molars, while the second term is given to the similarly opposed edges of the front teeth. The two surfaces of each tooth still to be named are those that are in contact with the neighboring teeth. The surface of each tooth directed toward the center of the jaw is called "mesial"; that toward the posterior portion of the dental arch is known as the "distal." There are four incisors in the upper and four in the lower jaw. The two middle ones are termed "central incisors"; the two outer, "laterals." Their cutting-edges, when the teeth are erupted, usually exhibit three protuberances, which, in use, soon become smooth through wear. The upper incisors, especially the centrals, are much larger than the lower ones, and in normal articulation overlap the latter. The upper incisors are inclined toward the median line, rendering the mesial surfaces somewhat longer than their corresponding distal surfaces. The incisors are wedge-shaped, thinning from the base at the gum toward

Fig. 15.



The Right Teeth of an Adult Twenty-two Years Old. Internal View. Lingual Surface.

the cutting-edges. These edges, in adult teeth, viewed anteriorly, represent a straight line. The general shape of an incisor thus anteriorly seen is, approximately, that of a square, though it narrows toward the neck. The mesial angle of the cutting-edge always inclines more than the distal. From this tapering of the crowns of the teeth toward their necks result more or less V-shaped spaces, which vary in different mouths. In some instances we meet with teeth of which the crowns are almost square, in which case the intervening spaces at the necks are quite small; while between teeth which exhibit broad cutting-edges and narrow necks we observe large V-shaped spaces.

The upper incisors usually have single roots, which are more or less conical toward the apices.

The labial surfaces of the upper incisors, especially in young subjects, are mostly marked by slight longitudinal depressions and elevations, which, through wear, gradually disappear with advancing age. In adults the labial surfaces are more or less smooth and slightly convex. In some instances we meet with transverse furrows or pits in these surfaces, which, however, must be regarded as abnormalities. The enamel at the gingival border of the labial surface terminates in a curved, somewhat elevated ridge. The lingual surfaces are irregularly concave. The periphery is bounded by a more or less prominent ridge of enamel, which, toward the margin of the gum, forms what is known as the *basal ridge* or *cingulum*. This basal ridge is frequently found to be divided by a deep groove or pit, which, in the majority of such cases, soon becomes the seat of caries. The boundary line of the enamel on the lingual surface is curved similarly to that of the labial surface. These ridges, as they turn into the mesial and distal surfaces of the incisors, take a downward course, following the festoons of the gum, and meet with the enamel ridge of the labial surface, producing a V-shaped appearance in both the mesial and distal surfaces of the teeth.

The *upper central incisors* (Nos. 8 and 9) occupy the center in the dental arch, being the broadest of the incisor teeth. Their roots are almost cylindrical, and gradually taper from the neck toward the apex.

The *upper lateral incisors* (Nos. 7 and 10) are smaller than the centrals. The mesial angle of their cutting-edge usually overhangs more than that of the central incisors, in consequence of which their distal angles appear more rounded. Their roots are compressed laterally, and taper from crown to apex, corresponding in length to those of the central incisors.

The *lower central incisors* (Nos. 24 and 25) are the smallest teeth in the dental arch. They are even smaller than the upper laterals. Their general outline is the same as that of the upper laterals, but the angle of their mesial surfaces is much less overhanging. Their lingual surface is usually smooth and but slightly concave. The roots of these teeth are more compressed laterally than those of the upper laterals.

The *lower lateral incisors* (Nos. 23 and 26) are somewhat wider than the centrals of the lower jaw, yet in every other respect their appearance is the same as that of the central incisors, although their roots are a little longer and heavier.

The *upper canines*, *eye-teeth*, or *cuspids* (Nos. 6 and 11) occupy a prominent position on either side of the incisor teeth. They form the corners of the dental arch, and are in every respect more stoutly built than the incisors. The crown terminates in a more or less blunt point, from either side of which a rounded cutting-edge slopes away and becomes continuous with the mesial or distal surface. The cutting-edge of the mesial surface is somewhat shorter than that of the distal surface. By this difference in the length of the cutting-edges we are enabled to distinguish the teeth belonging to the right from those of the left side of the mouth. Upon the labial surface of an upper cuspid tooth we observe a somewhat prominent ridge, which extends from the summit of the cusp to the neck. This ridge renders the surface more convex than the corresponding labial surface of an incisor tooth. In the median line of the lingual surface of an upper cuspid we also observe a ridge, the direction of which is identical with that of the labial surface. In some instances, where this ridge joins the cingulum, it develops into a regular small cusp, which in shape is not unlike that of a lower first bicuspid tooth. The mesial and distal surfaces are of a triangular form, similar to those of the incisor teeth; but their base is much broader. The roots of the upper cuspid teeth are much stouter and longer than those of the incisors, and are usually somewhat compressed laterally. The position of these roots in the mouth can easily be determined, since they are marked by a prominent ridge upon the external surface of the maxillary bones, the canine eminences.

The shape of the *lower cuspids* (Nos. 22 and 27) does not differ much from that of the upper ones, although they are smaller in every respect. The ridges upon their lingual surfaces are not so prominently developed, and their roots are shorter.

The *premolars* or *bicuspids*, eight in number (Nos. 4, 5, 12, 13, 20, 21, 28, and 29), are arranged in pairs, both in the upper and lower jaws, posterior to the cuspids. Their crowns are quadrilateral; but the buccal portion of the crown is larger than its lingual half, as is especially noticeable in the first bicuspids. The shape of the buccal surface of a bicuspid is similar to that of the cuspid of the same side of the mouth; the ridge, however, extending from the summit of the cusp to the margin of the gum, is not so strongly marked. The grinding-surface of a bicuspid, as the name implies, exhibits two cusps, of which the buccal is the largest. These cusps are separated from each other by a furrow which, in some teeth, is quite deep, and often becomes the seat of caries. The mesial and distal portions of this furrow are bounded by a small ridge of enamel, continuous with the sloping lingual and buccal edges of the cusps. The cutting-edges are similar to those of the cuspid of the same side of the dental arch.

The *upper bicuspids* (Nos. 4, 5, 12, and 13) are somewhat larger than those of the lower jaw, and their lingual cusps are more developed. The lingual portion of the crown of the first upper bicuspid is narrower antero-posteriorly than its buccal half. The shape of the crown of the second bicuspid is more nearly square, and the entire tooth a little stouter than the first. The root of the first upper bicuspid always is much compressed laterally, and, as a rule, contains two pulp-canals. Sometimes its root is bifurcated, while the upper second bicuspid seldom has more than one root, or one pulp-canal.

The *lower bicuspids* (Nos. 20, 21, 28, and 29) are smaller than those of the upper jaw. Their crowns are roundish and somewhat bent inward. Their roots are conical. The first lower bicuspid is the smallest of the bicuspids. Its outer cusp is much higher than the inner one, which is but slightly developed. From the buccal to the lingual cusp extends a small ridge, on either side of which is sunken a little pit, a favorite seat of decay. The second lower bicuspid is larger than the first, and its lingual cusp is more developed than that of the first lower bicuspid.

If we compare the incisors with the cuspids and bicuspids, we find that there exists a typical analogy between their shapes, which, however, is not the case if we compare the incisors with the molars.

The *molar teeth* (Nos. 1, 2, 3, 14, 15, 16, 17, 18, 19, 30, 31, and 32) are the largest in the mouth, and occupy the posterior portion of the dental arch. Normally there are six molars in each jaw, three on either side. The third molar, also called wisdom-tooth, is, however, frequently missing, and in a crowded dental arch may remain unerupted. This deficiency is, in some families, characteristic and hereditary. The crowns of the first molars are larger than those of the second, and, in turn, the crowns of the second are larger than those of the third. The grinding-surface of a molar is of a more or less square shape, with rounded angles, and is made up of four or five cusps. The mesio-buccal cusp of a molar usually is a little larger than the others, which fact enables us to determine to which side of the mouth the tooth belongs.

The crowns of the *upper molars* (Nos. 1, 2, 3, 14, 15, and 16), especially the first and second, usually exhibit a cusp upon each of their angles, of which the mesio-lingual is the largest. The mesio-buccal cusp is connected with the mesio-lingual one by a ridge which runs along the mesial border of the grinding-surface. Sometimes we observe upon the mesio-lingual border of the crown of the first and second upper molars a small extra cusp, separated from the large mesio-lingual by a deep furrow.

The furrows separating the cusps run over the buccal and lingual borders of the grinding-surface. The furrow upon the lingual surface usually terminates in a more or less deep pit, which, together with the above-described fissures of the grinding-surface, furnishes a favorable locality for the development of caries. The roots of each upper molar are usually three in number,—two buccal, much compressed antero-posteriorly, and one lingual or palatal. The lingual root is the stoutest of the three, conical in form, diverging from the axis of the crown toward the palate, and often slightly curved in the direction of the buccal roots. The crown, as well as the roots of the upper third molar, or wisdom-tooth, is liable to great variations. In the majority of instances we find the crown of a third upper molar much smaller and shorter than that of the first or second molar. This molar sometimes has only one straight, short root, but in some instances it is supplied with three,—the typical number,—four, or even five. Occasionally the roots of the wisdom-teeth are normally developed, like those of the first and second molars; mostly, however, they are but rudimentary and more or less compressed, or even conglomerated into one root.

The grinding-surfaces of the *lower molar teeth* (Nos. 17, 18, 19, 30, 31, and 32) usually exhibit five cusps, separated from one another by deep furrows, representing a regular cross. The posterior arm of this furrow, as a rule, bifurcates and winds around the fifth cusp. The lingual and buccal portions of the furrow extend into the lingual and buccal surfaces of the tooth. Especially upon the buccal surface of the lower molars the furrow is quite deep, terminating in a pit, which, like that of the upper molars, frequently decays. The cusps are placed, one at each of the four angles of the grinding-surface, while the fifth cusp, the smallest, is situated upon the posterior border of this surface. The lower molars, with the exception of the third, usually are implanted with two roots, which in the jaw occupy an antero-posterior position and are much compressed in the antero-posterior direction. Occasionally we observe that the mesial root of the first lower molar is bifurcated.

The Temporary, Deciduous, or Milk Teeth.—In the mouth of an infant, about the sixth month after its birth, we observe the appearance of the first teeth, which belong to the so-called "*temporary*" or "*deciduous*" set. The complete denture of a child is comprised of twenty teeth, which are noted as follows:

$$\mathrm{T\ I}\ \tfrac{2}{2};\ \mathrm{T\ C}\ \tfrac{1}{1};\ \mathrm{T\ M}\ \tfrac{2}{2} = 20.$$

(See Fig. 16.)

The temporary incisor and cuspid teeth are similar to those of the permanent set, though much smaller. The bicuspids are absent. Their arrangement in the dental arch is the same as that of their respective successors; but the temporary molars occupy on either side of the cuspids the places which in the permanent set are filled by the bicuspids.

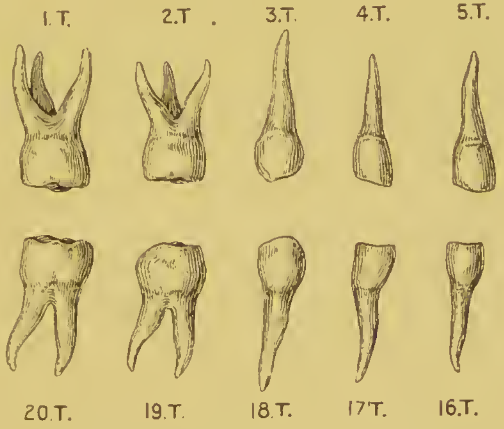
The crowns of the temporary teeth are large in proportion to their necks and roots, the enamel terminating in a rather thick ridge, which is a characteristic feature of all the temporary teeth.

In the illustration I have adopted the numbering of the temporary teeth from one to twenty, adding a T, to distinguish them from the permanent teeth.

No. 1 T, the right upper second molar, is the largest of the upper molars. In shape its crown resembles that of the first permanent upper molar; but its roots, besides being smaller, diverge much more from the center than do those of the permanent teeth. The grinding-surface is surmounted usually by four, sometimes by five, cusps, arranged in the same manner as those of the first permanent upper molar.

No. 2 T, the right upper first molar, is considerably smaller than No. 1 T. Upon the grinding-surface we usually find but two cusps, one upon the buccal, the other upon the lingual aspect. They are divided by a deep furrow. There are three roots, which in shape and arrangement are similar to those of molar No. 1 T, but somewhat smaller.

FIG. 16.



THE RIGHT TEMPORARY OR DECIDUOUS TEETH.

No. 3 T, the right upper cuspid, while in its principal characteristics similar to its successor, in proportion is much smaller and shorter than the permanent cuspid. It is implanted by a single, almost cylindrical root.

Nos. 4 T and 5 T, the right upper lateral and central incisors, except in being smaller than their successors, are in their general outlines much like the latter, only their crowns are shorter in proportion to those of the corresponding permanent teeth. They invariably have but one root, of a conical shape.

Temporary teeth Nos. 6, 7, 8, 9, and 10 of the upper jaw, as well as *Nos. 11, 12, 13, 14, and 15* of the lower jaw, are identical in character with their fellows of the opposite side, with the exception that the forms of their crowns are reversed.

Nos. 16 T and 17 T, the right lower central and lateral incisors. The principal difference between these teeth and their permanent successors is that the former are much smaller, have a more or less conical root, and their enamel terminates at the neck in a thick ridge, which is common to all temporary teeth.

No. 18 T, the right lower cuspid. Its crown usually is somewhat longer than that of the upper temporary cuspid, but not so stout; while its root, like that of No. 3 T, is nearly conical.

No. 19 T, the right lower first molar. Its crown is smaller than that of No. 20 T. Upon its grinding-surface we commonly find four small cusps. It is implanted by two roots, flattened antero-posteriorly, and diverging considerably from the center.

No. 20 T, the right lower second molar, is the largest of all the temporary molars. Its grinding-surface is surmounted by four, sometimes five, cusps, arranged in the same manner as those of the first permanent lower molar. It has two roots, which in shape and position are similar to those of the first temporary molar, though much larger, and in some instances almost as stout as those of the permanent lower molars.

CHAPTER IV.

INDIVIDUAL CHARACTERISTICS OF THE TEETH.

Distinguishing Features between the Temporary and the Permanent Teeth.—The main peculiarity of temporary teeth is that they are much smaller than the permanent ones. The enamel of the temporary teeth terminates at the neck in a rather thick ridge, whereby the necks of these teeth appear much smaller in proportion than those of the permanent teeth. The temporary incisors offer another marked characteristic in their smooth cutting-edges, while those of permanent teeth, in the juvenile condition, are each of them surmounted by three small protuberances.

The temporary cuspids are much shorter, narrower, and have a less pointed cusp than their permanent successors.

The crown of a first temporary molar is so typical that it scarcely will be mistaken for a permanent tooth. Its roots are much smaller than those of a permanent molar, and diverge considerably from the center.

The second temporary molars, on the contrary, while in the jaws, may sometimes be confounded with a permanent sixth-year molar; but as this always is the fifth tooth from the center, its position will aid us in making the distinction.

Distinguishing Peculiarities between the Upper and Lower Permanent Teeth.—The principal difference existing between the incisors of the upper and those of the lower jaw is that the crowns of the former are much broader than those of the lower incisors. While the crowns of the latter are the smallest in the mouth, they are, at the same time, noticeably compressed laterally toward their necks.

The upper cuspids, or eye-teeth, are the stoutest teeth possessing single roots, much larger than the lower ones. The cingulum and the ridge upon the lingual surface of the lower cuspids, which are so marked in the upper, are but little developed.

The main difference between the bicuspids of the upper and those of the lower jaw is that the crowns and roots of the former are somewhat compressed antero-posteriorly, while the roots and the crowns of the latter are nearly cylindrical. There is also a difference in their lingual cusps, which in the upper bicuspids are long, in the lower short, sometimes merely rudimentary. This last is especially often the case with the first lower bicuspid.

To discriminate between the first and second molars of the upper and lower jaws, it is only necessary to notice the number of their roots, since the former usually exhibit three, the latter mostly but two. Another peculiarity of the upper molars is the arrangement of the furrow upon the grinding-surface, which somewhat resembles the letter H, while the fissure of the lower molars represents a cross. The upper and lower wisdom-teeth, or third molars, might sometimes be confounded with each other, because both are often implanted with a single conglomerated root. The crown of a lower third molar, however, even though altered, usually represents the general type of the lower molars. Upon the grinding-surface of a lower third molar, therefore, we mostly see the fissure between the cusps more or less in the form of a cross.

In numbering the teeth, the writer has adopted the system employed in dental registers and examination tables. (See Figs. 14 and 15.)

No. 1. Right upper third molar, or *wisdom-tooth*. This is the smallest of the three molars. The crown usually exhibits but three cusps, one upon the lingual and two upon the buccal aspect.

The mesial cusp is the largest of the three. Usually the third molar has one root, sometimes it has two; in well-developed teeth three roots may be present. In the last case the grinding-surface is surmounted by four cusps, similar in arrangement to those of the other molars.

No. 2. Right upper second molar. This is a trifle larger than No. 1, but smaller than No. 3. Its cusps and roots are similar to those of No. 3, though its crown is more rounded. Its mesio-buccal cusp is larger than the distal one, and the tooth, as a rule, is possessed of three distinct roots.

No. 3. Right upper first molar. This is the largest of the upper molars. Its grinding-surface is of a rhomboidal form, the mesio-buccal and linguo-distal angles being acute, while the disto-buccal and mesio-lingual angles are obtuse. Its mesio-buccal cusp is larger, somewhat lower, and more rounded than the disto-buccal one. It has three distinct roots.

No. 4. Right upper second bicuspid. The crown of this tooth is larger than that of any other bicuspid. Its lingual cusp is slightly higher and better developed than that of the first upper bicuspid. The mesial portion of the buccal cusp of the cutting-edge is more obliquely inclined than the distal. The root is usually single, somewhat compressed laterally, and holds but one pulp-canal.

No. 5. Right upper first bicuspid. This tooth is a trifle smaller than No. 4, especially in the lingual portion of its crown. The mesial cutting-edge of the buccal cusp is directed more obliquely downward than that of the distal. The root is usually bifurcated, or a groove runs longitudinally on both sides of the root in the median line, indicative of two pulp-canals, which, in most instances, are present.

No. 6. The right upper cuspid has a single, pointed cusp, of which the mesial cutting-edge is directed more obliquely downward than the distal. It has one long, stout root.

No. 7. Right upper lateral incisor. Its crown is much smaller than that of a central, No. 8 or 9. The mesial angle of the cutting-edge is more overhanging than the distal one, the latter being more rounded. It has a single compressed root.

No. 8. Right upper central incisor. The crown, like that of No. 9, is broad and square in its labial aspect. The mesial angle of the cutting-edge is more acute than the distal, which is somewhat rounded. It has a single, more or less conical root.

The teeth Nos. 9, 10, 11, 12, 13, 14, 15, and 16 are identical in shape with the corresponding teeth of the opposite side of the dental arch, with the exception that the general shape of their crowns is reversed.

No. 17. Left lower third molar, or *wisdom-tooth.* Its crown is somewhat larger than that of the upper wisdom-tooth, but it is always the smallest of the lower molars. The grinding-surface is surmounted by four or five cusps. When there are four, the mesio-buccal cusp is the largest; if, however, five cusps be present, three of them usually are upon the buccal portion of the crown. In most instances it has one or two more or less conical roots, curved toward the posterior portion of the jaw.

No. 18. Left lower second molar. The crown is nearly square, somewhat larger than that of No. 17, but not quite as large as that of No. 19. The grinding-surface is surmounted by four or five cusps, of which two are situated upon the lingual and two or three upon the buccal portion of the crown. The lingual cusps are always a little higher, but more pointed, whereas the buccal cusps are broad and round. By the shape and position of these cusps we are enabled to determine correctly to which side of the dental arch the molar belongs. This molar usually has two compressed roots, of which the anterior sometimes holds two pulp-canals.

No. 19. Left lower first molar. Its crown is almost square. It is the largest of the lower molars. It usually has five cusps, of which two are situated upon the lingual and three upon the buccal portion of the crown. The lingual cusps are pointed, and a little higher than the three buccal ones, the latter being rounder, broader, and a little lower. Of the buccal cusps, the mesial is usually the largest. This molar generally has two, but occasionally three roots, two anterior and one posterior, and it almost always contains one posterior and two anterior pulp-canals.

No. 20. Left lower second bicuspid. The crown is larger than that of No. 21, its lingual cusp a little lower than the buccal. The lingual cusp of this tooth is much more developed than that of the first lower bicuspid. The mesial cutting-edge of the buccal cusp usually is more obliquely inclined than the distal. The root is mostly single and conical.

No. 21. Left lower first bicuspid. The crown is the smallest of any of the bicuspid teeth, nearly round in circumference, and somewhat bent upon the root toward the lingual portion of the dental arch. The lingual cusp is very small, though pointed, and connected with the buccal cusp by a ridge of enamel which divides the grinding-surface and thereby produces two deep pits. The mesial cutting-edge of the buccal cusp is more obliquely inclined than the distal. It usually has a single conical root.

No. 22. Left lower cuspid. The crown is narrower, but sometimes longer than that of an upper cuspid. Its lingual surface is almost flat, or slightly concave, and the mesial cutting-edge is more obliquely inclined than the distal. Its root is mostly single, but flattened.

No. 23. Left lower lateral incisor. Its crown is somewhat narrower than that of an upper lateral, but not quite so narrow as that of a lower central incisor. The mesial angle of the cutting-edge usually is similar to that of the distal. The root is much more compressed laterally than that of an upper lateral incisor.

No. 24. Left lower central incisor. The crown is narrower than that of any other incisor tooth, being much compressed laterally at the neck. Its root is similar in shape to that of a lower lateral incisor.

The teeth Nos. 25, 26, 27, 28, 29, 30, 31, and 32 are identical in shape with the corresponding teeth of the opposite side of the dental arch, with the exception that the general configuration of the crowns is reversed. It should be noted, however, that in the lower laterals and central incisors both angles of the cutting-edges are about equal. It is in most cases impossible to determine to which side of the dental arch a lower incisor belongs.

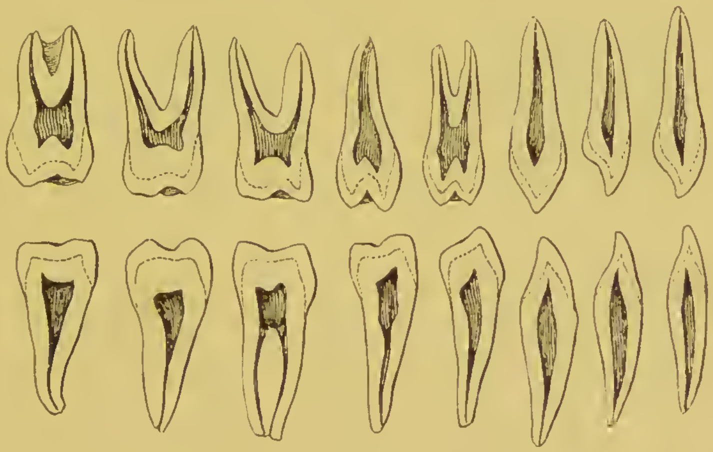
CHAPTER V.

THE PULP-CHAMBERS OF THE TEETH.

EVERY tooth incloses a central cavity, of which the shape corresponds to that of the exterior of the tooth. The coronal portion of this cavity is called the *pulp-chamber*, while the portion in the root of the tooth is known as the *root-canal*. It is of the utmost importance to the dental practitioner to be thoroughly familiar with the forms and positions of the pulp-chambers of the teeth, since a proper diagnosis of the different diseases of the dental pulp cannot be made without this knowledge. Furthermore, a dentist not well acquainted with the anatomy of the pulp-chamber is liable to expose a pulp unintentionally during the preparation of a cavity for filling. Within every cusp of the molars, bicuspids, and cuspids we find a corresponding elevation in the pulp-chamber, while in the crown of an incisor the cavity is somewhat bifurcated.

The pulp-chambers, as well as the root-canals, are filled by myxomatous connective tissue, interwoven with blood-vessels and nerve-fibers, termed the *dental pulp.* This tissue also fills the protuberances under the cusps of the teeth, these portions being called the *horns* of the pulp. The latter are the points which, through caries, easily become exposed and diseased. Although we often find carious cavities, and, consequently, exposures of the pulp, about the necks of the teeth, nevertheless in the majority of instances the dental pulp becomes exposed at one or more of its horns.

Fig. 17.



Left Teeth in Linguo-Labial and Linguo-Buccal (Sagittal turning to Frontal) Sections. Reversed to the Right Side.

G. Carabelli* was the first to give illustrations of the pulp-chambers of the teeth, in their various places, but without correct measurements. He published elaborate drawings of the pulp-chambers of both the temporary and the permanent teeth. Upon comparing the charts of Carabelli, however, we find that the pulp-chambers of the teeth there depicted do not correspond to those usually met with in this country, which difference may perhaps be explained by the fact that the teeth used by Carabelli were of a different type from those of our generation.

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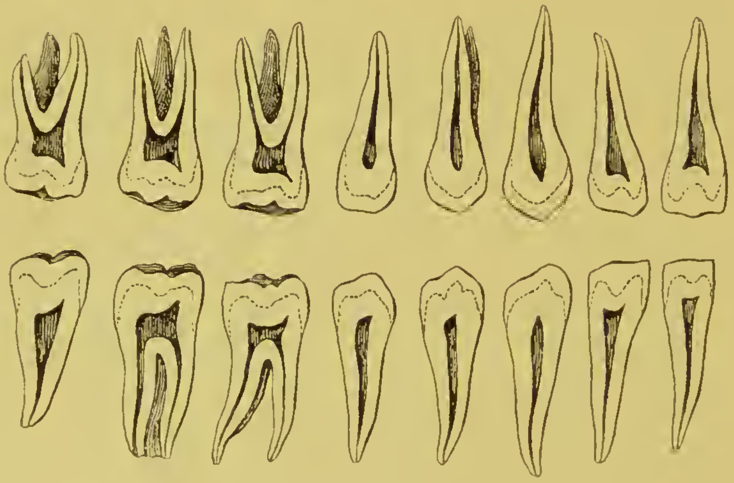
* Systematisches Handbuch der Zahnheilkunde, 1844.

To arrive at satisfactory conclusions in the study of the pulp-chambers of the human teeth, it would be necessary to examine many complete sets of different ages, constitutions, and shapes. But the author has only been able to obtain a single set of thirty-two perfect teeth, which were imported from Tramond, of Paris. These teeth are alleged to have come from the mouth of a girl about twenty-two years of age. Correct drawings were made of them, as represented in Figs. 14 and 15. Afterward the sixteen teeth of the left side were ground upon a corundum-wheel, exposing the mesial or frontal aspects of the pulp-chambers, as represented in Fig. 17. The other sixteen teeth, belonging to the right side of the dental arch, were prepared as represented in Fig. 18, exposing the labial aspect (respectively buccal or sagittal) of the pulp-chambers. It is a well-known fact that, at different ages of the individual, the pulp-chambers vary greatly in size and shape; yet, with the knowledge derived from observations made on other teeth, as well as from the chart published by Arkövy,* we may regard the above teeth as normal for the age of twenty-two years. It is likewise established that the pulp-chambers of the teeth decrease in size with advancing age, and especially when the

Fig. 18.



Right Teeth in Lingual and Buccal (Frontal turning to Sagittal) Sections.

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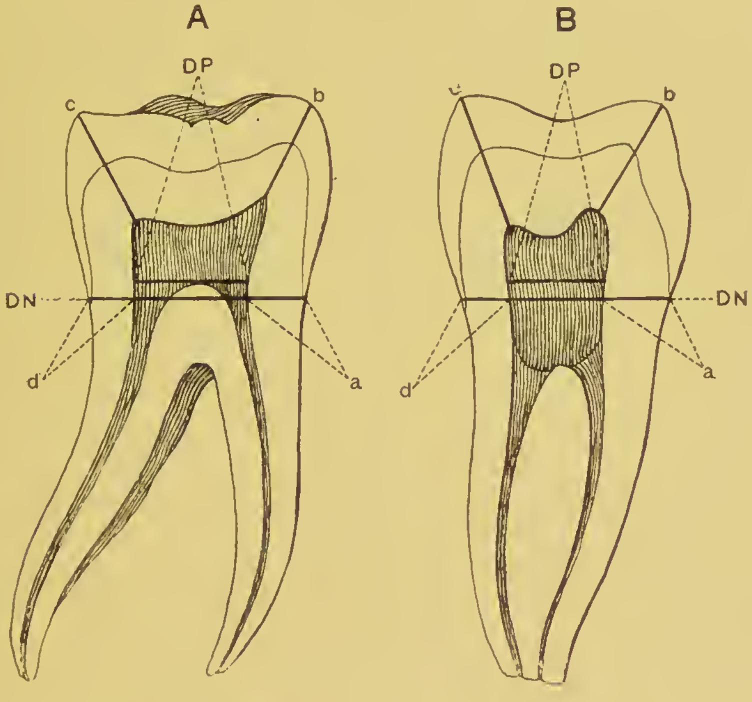
* Diagnostik der Zahnkrankheiten, 1885.

enamel of the teeth becomes worn away. In these instances, not only all the horns of the pulp gradually disappear, but sometimes almost the whole pulp-chamber becomes obliterated by the formation of secondary dentine. This condition of the pulp-chambers does not so much depend upon the age as upon the habit of the individual to whom the teeth belong, and upon the articulation of the teeth. Some individuals, especially those of a nervous temperament, have the habit of grinding their teeth during sleep, whereby the enamel of the antagonizing surfaces soon becomes worn off. In other instances a person loses some of the molars and bicuspids, with the result that he is able to masticate with the front teeth only, in which case the enamel of these teeth is soon worn away. In such cases, we observe in the vicinity of the pulp-chamber corresponding to the place of injury

Fig. 19.



Key to the Measurements of the Pulp-Chambers of the Teeth.

A, *sagittal section of the right lower first molar.*—*DN*, diameter of neck; *DP*, diameter of pulp-chamber; *a*, diameter between pulp-chamber and mesial surface; *b*, diameter between anterior horn of pulp-chamber and external surface of cusp: *c*, diameter between posterior horn of pulp-chamber and external surface of cusp; *d*, diameter between the pulp-chamber and distal surface. **B**, *frontal section of the left lower first molar.*—*DN*, diameter of neck; *DP*, diameter of pulp-chamber: *a*, diameter between pulp-chamber and buccal surface; *b*, diameter between buccal horn of pulp-chamber and external surface of cusp; *c*, diameter between lingual horn of pulp-chamber and external surface of cusp; *d*, diameter between pulp-chamber and lingual surface.

on the grinding- or cutting-surfaces of the teeth, a formation of secondary dentine, although the individual may not be more than thirty or thirty-five years of age. On the other hand, it sometimes occurs that with people from forty-five to fifty-five years of age there remains a complete set of teeth, with their cusps, as well as the horns of the pulp, still present. Furthermore, where we find defects upon the neck of the tooth, called erosion, we observe a great diminution in the size of the pulp-chamber, and especially that portion corresponding to the place of injury in the neck of the tooth. In some chronic constitutional diseases, particularly in anæmia, we often meet with teeth the pulp-chambers of which are unusually large.

Notwithstanding the great differences existing in the size and form of the pulp-chambers of the teeth, it is of great value to know, approximately, the thickness of the dental tissue between the pulp-chamber and the periphery of the tooth, and consequently the author has made correct measurements of the thirty-two teeth in twelve different places, as explained by Fig. 19, *A* and *B*.

Table of Measurements of Pulp-Chambers in Millimeters.

NUMBERS.	Labial Sections, respectively Buccal or Sagittal.						NUMBERS.	Mesial or Frontal Sections.					
	a	*b*	*c*	*d*	D P	D N		*a*	*b*	*c*	*d*	D P	D N
1	2.1	4.7	4.6	2.1	2.9	7.1	9	2.3	4.1	...	2.6	1.6	6.5
2	2.0	5.4	5.6	2.3	3.5	7.8	10	1.9	5.6	...	2.0	1.9	5.8
3	2.8	4.8	5.0	2.4	2.3	7.5	11	2.5	5.8	...	2.8	2.2	7.5
4	2.0	4.7	...	2.1	1.0	5.1	12	1.6	3.9	4.5	2.1	4.6	8.3
5	1.9	4.9	...	1.7	1.0	4.6	13	2.0	5.2	5.8	2.3	4.2	8.5
6	2.1	6.9	...	2.4	1.5	6.0	14	3.4	5.5	5.4	3.2	4.6	11.2
7	1.6	3.6	...	1.7	1.5	4.8	15	3.4	5.4	6.4	2.4	5.6	11.5
8	2.4	6.5	...	2.2	1.9	6.5	16	2.5	5.5	5.8	2.4	5.9	10.8
25	1.4	4.1	...	1.6	1.0	4.0	17	2.2	5.1	4.9	2.5	3.2	7.9
26	1.6	4.0	...	1.7	0.8	4.0	18	2.4	6.3	7.0	2.1	4.3	8.8
27	1.9	6.1	...	2.4	1.0	5.1	19	2.3	5.0	6.2	2.0	4.4	8.7
28	2.0	3.5	...	1.8	0.9	4.7	20	1.3	4.0	5.1	2.5	2.5	6.8
29	1.8	4.0	...	2.0	1.2	5.0	21	1.7	4.7	4.4	1.9	2.5	6.1
30	2.4	5.1	4.9	2.5	3.6	8.5	22	2.6	4.4	...	2.7	2.5	7.8
31	2.3	5.4	6.5	2.5	3.8	8.6	23	2.0	3.5	...	2.4	2.1	6.5
32	2.2	5.2	6.0	2.6	3.3	8.1	24	1.8	3.8	...	2.1	1.3	5.3

TABLE OF MEASUREMENTS REGARDING THE SITUATION OF THE HORNS OF THE PULP.

DISTANCES OF THE HORNS OF THE PULPS FROM THE CUTTING-EDGES OR THE CUSPS OF THE MOLARS.

Measurements in millimeters. After Arkövy.

		3d Molar.				2d Molar.				1st Molar.				2d Bicusp.		1st Bicusp.		Cuspid.	Lateral Incisor.	Central Incisor.	Central Incisor.	Lateral Incisor.	Cuspid.	1st Bicusp.		2d Bicusp.		1st Molar.				2d Molar.				3d Molar.			
		Distal.		Mesial.		Distal.		Mesial.		Distal.		Mesial.																Mesial.		Distal.		Mesial.		Distal.		Mesial.		Distal.	
		li	la	li	la	li	la	li	la	li	la	li	la	li	la	li	la							la	li	la	li	la	li	la	li	la	li	la	li	la	li	la	li
UPPER TEETH.	A man 17 years of age with normally developed teeth.	4	3.5	4.	4.	4.	4.	4.	3.5	5.	4.5	4.	3.5	4.5	3.5	4.	3.5	3.5	3.	3.5	3.5	3.	2.5	3.5	4.	3.5	4.	3.5	3.5	4.	5.	4	4.5*	4.	—	—	—	—	—
	A man 33 years of age with normally developed teeth.	—	—	—	4.	—	4.5	4.*	4.	4.5	4.5	4.	4.	5	4.5	5.	4.	5.	6.	7.	7.	6.	5.	5.	4.5	5.	4.5	5.	4.	5.	5.5	5.	6.*	5.	—	5.	4.5	—	—
	A man 37 years of age with teeth very much worn.	—	—	4.	5	—	5.5	4.*	5.	4.5	4.	5.	4.	4.5	4.	4.	4.	4.	4.5	5.	5.	5.	4.	4.	4.	3.5	3.	4.	5.	4.	4.5	5.	5.*	5.5	—	—	—	—	—
LOWER TEETH.	A man 17 years of age with normally developed teeth.	—	4.**	4.	3.	5.	5.	4.	4.	4.5	4.	4.	3.	4.5	3.	3.5	3.	2.5	3.	2.	2.	3.	3.	3.	3.5	3.5	4.	3.5	4.	4.	4.5	4	4.5	4.5	—	—	—	—	—
	A man 33 years of age with normally developed teeth.	—	6.**	5.5	5.	6.	4.	5.	4.5	5.5	4.5	5.	3.5	5.	4.	4.	3.5	4.5	4.5	5.	5.	5.	4.	3.	4.	5.	4.	3.5	5.	4.	4.5	5.	6.	4.5	6.	5.	5	6.	6.5
	A man 37 years of age with tooth very much worn.	—	4.5**	5.	5.	5.	4.5	5.	4.	4.5	4.5	5.	4.	4.5	3.5	4.	4.	4.	4.	4.	3.	3.5	4.	4.	4.	3.5	5.	4.	4.5	4.	4.5	4	4.5	4.	5.	5.	5.	5.**	—

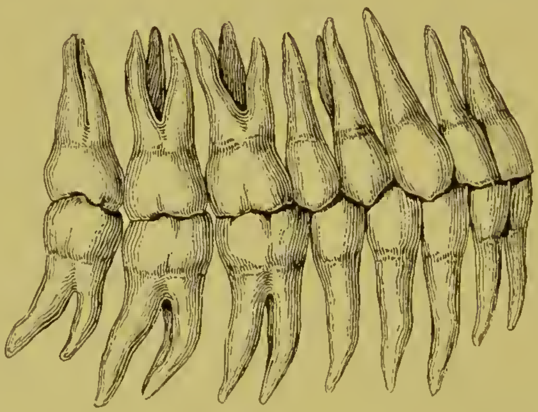
The numbers marked * signify that out of the three horns of the pulp the one corresponding to the palatine root was regarded as the mesial and lingual, while the third and only distal horn always belongs to the labial surface. The numbers marked ** designate that the only distal horn of the pulp has been regarded as belonging to the labial surface.

CHAPTER VI.

THE ARTICULATION OF THE TEETH.

When we examine the occluding surfaces of a perfect set of human teeth and the manner in which they articulate, we come to the conclusion that the articulation of the teeth is a most wonderful device of nature, forming quite a complicated piece of mechanism. The principles of articulation, both from a practical and a scientific standpoint, are of the greatest importance, and therefore ought to be studied closely by every dental student. The articulation of the teeth is based upon certain geometrical and mechanical laws first described by W. G. A. Bonwill.*

Fig. 20.



Articulation of a Perfect Set of Teeth of the Right Side—External Surface.

In observing this articulation, we find that, in the human jaw, a straight line drawn from the buccal surface of the first bicuspid to the internal angle of the condyloid process of the lower maxilla will almost touch all the buccal surfaces of the bicuspids and molar teeth. This shows that the teeth named are arranged in an almost straight row from the cuspid to the inner angle of the condyloid process of the lower jaw. We also observe that, with the exception of the upper third molars, every tooth articulates with two in the opposing jaw. (See Figs. 20 and 21.) Thus, if a tooth is lost, the antagonist, being retained in its position, is useful to a certain extent, and the regularity of the dental arch is not materially disturbed. Again, articulation has been wisely arranged in this manner to offset the work of another law of nature, by the operation of which every tooth not articulating with at least one opposing tooth gradually elongates, and eventually is cast out of the jaw. We observe that, in a normal articulation, all the teeth of the upper jaw more or less overlap those of the lower, although it must be admitted that a perfectly articulating set of teeth is a rarity in the human mouth. In studying the articulation of the bicuspids and molars, we find that every cusp correctly fits between cusps in the opposing jaw; and by this arrangement of cusps and depressions the grinding-surface is materially increased. The external or buccal cusps of the upper bicuspids and molars are arranged a little outside of the lower arch,—a disposition which enables the teeth of the upper jaw, when the pterygoid muscles are brought into action, to articulate with all the teeth of the lower jaw. The lingual cusps of the upper bicuspids and molars are somewhat higher and less pointed than the corresponding outer cusps. In the lower teeth we find this arrangement reversed, and observe that the outer cusps of the bicuspids and first molars are the longer and rounder, while the inner or lingual cusps are the shorter and more pointed. The result of this reciprocation evidently is that, when the lower jaw is moved laterally by the pterygoid muscles, the buccal and lingual cusps of the upper teeth on one side of the mouth play upon the buccal and lingual cusps of the lower teeth, while the lingual cusps of the upper jaw on the opposite side of the mouth articulate with the buccal cusps of the lower teeth.

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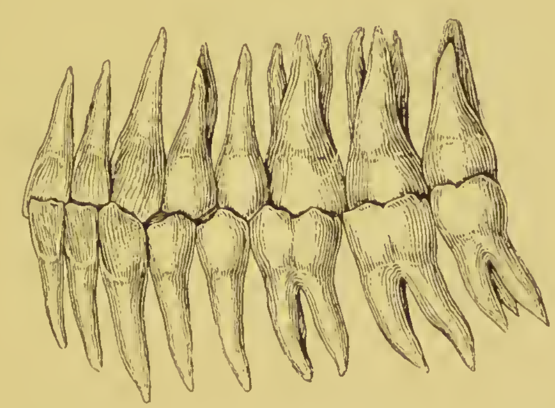
* "The Geometrical and Mechanical Laws of the Articulation of the Human Teeth." Harris's "Principles and Practice," twelfth edition.

Fig. 21.



Articulation of a Perfect Set of Teeth of the Right Side—Internal Surface.

Hence the teeth not only possess a larger extent of grinding-surface with small proportional bulk, but considerable energy is saved in *mastication*. At the same time, the pressure upon the teeth exerted by the muscles of mastication is more or less equalized through the entire dental arch. If we examine different sets of teeth, we shall notice that great variations exist in the lengths of the so-called *overbites*. If the upper front teeth overlap the lower ones but little, we invariably find short cusps upon the bicuspids and first molars, while, on the contrary, when the overbite is long these cusps are long and pointed, provided all the teeth occupy their proper positions. On examining the plane of the grinding-surface of the lower bicuspids and molars, we find that the second and third molars stand considerably higher than the first, yet the three crowns form a gradual slope. Regarding the position of the roots of the lower second and third molars, we observe that while their crowns are tilted forward, their roots, on the contrary, are directed toward the condyloid process of the jaw, by which arrangement this gradual slope is accomplished. In consequence of this slope in the lower dental arch, the second and third molars of the upper jaw also assume a slanting position upward, rendering the first upper molar the longest of the molar teeth. The object of this arrangement evidently is that, when by the sliding movements of the lower jaw the condyloid process is brought forward, the second lower molar articulates against the first upper one, which, being longer than the second and third, opens the jaw sufficiently to allow the articulation of the cutting-edges of the upper and lower front teeth as well as the points of the cusps of the bicuspids. Hence the pressure, which otherwise would bear upon the molars only, is equally distributed upon the side as well as the front portion of the dental arch.

When, because of the loss of the back teeth, a patient for a number of years masticates entirely with the front teeth, the muscles of mastication gradually become contracted, the condyloid process leaves its normal place in the glenoid fossa, and occupies a more anterior position. In such cases we observe a slight protrusion of the lower jaw, and the remaining teeth to be considerably reduced in length through mechanical abrasion, brought about by the lateral movements of the lower jaw. Their cutting-edges, formerly more or less sharp, are now broad and flat, similar in form to the grinding-surface of a much-worn bicuspid. In this instance an acquired abnormal articulation of the lower jaw is present, which, upon the restoration of the teeth to their original length, will cause the condyloid processes of the lower jaw to resume their former position in the glenoid fossæ.

From the article published by W. G. A. Bonwill I quote the following:

"*The Equilateral Triangle within the Main Triangle.*—The outline drawing (Fig. 22) may be thought ideal. But any one at all acquainted with geometry must be struck with wonder at the marvelous ingenuity of the contrivance based alone on the equilateral triangle. It will be seen that perfection must be the result, since each part is complete within itself and the whole supporting each individual part.

Fig. 22.

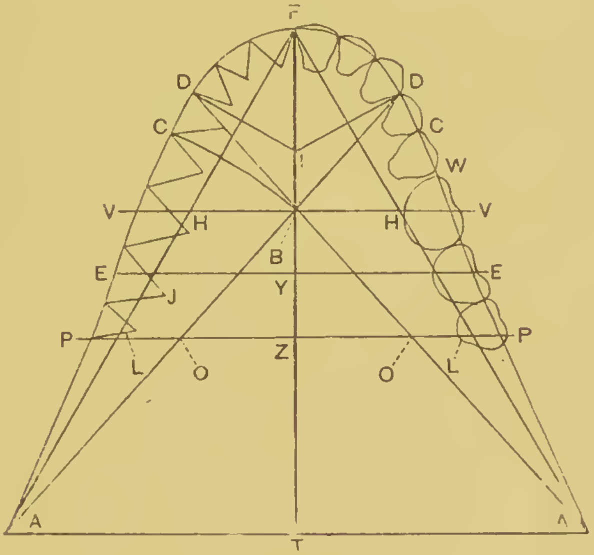


Diagram showing Equilateral Triangle of the Lower Jaw. (After W. G. A. Bonwill.)

"How have I arrived at this divination? The law is based upon the measurement of over two thousand human skulls. First make an equilateral triangle, four inches; A, A, F. Draw a line from T to F. What is the guide to form the arch? Know the actual width of the superior central, lateral, and cuspid at their greatest diameter from the mesial to distal surfaces, say $\frac{13}{16}$, as in Fig. 22. Measure this off with the dividers, and place one arm at F and describe an arc from D to D through I. Then place dividers at I, and intersect the line just made from

F, and it will be found that at D will be found the extremest point of the arch D, F, D, and will be the distal surface of the superior cuspid. Place the dividers at I, and describe the arc from D to D through F, which will constitute the normal and positive arch of the superior jaw. There will be an equilateral triangle from D, F, I on either side of the mesial line at F. The same will be found the base of each superior incisor.

"Next draw a line from A to D on either side, which will be the guide for the bicuspids and molars as to width and depth. Then, by placing the dividers at A and B, describe another arc to C, which will give the width of first superior bicuspid. The line from A to D passes through its palatal base, and will pass through center of base of triangle of this tooth. Form another triangle by drawing a line from H to H, through B, which will pass through the center of the first molar, and will give the width between the palatal surfaces or their depth or thickness. Placing the dividers at I and F, we intersect the line from F to T at Y. Draw a line through Y to E, E, forming another equilateral triangle. From B to F is now the radius of another arc, which intersects the line from D to A at V, and the line A to D at O. A line now drawn E to E through Y intersects the center of the second molar at E, E.

"Get half the distance between the points at E on the line from D to A, and the width of the first molar is made, and also the second, which is the angle of the equilateral of each. This leaves room between the first bicuspid and first molar, and is the width of second bicuspid; or it is shown by placing the dividers at A and Y, and intersecting line from D to A at W, same as from B to C, for the first bicuspid's width. The distance from D to D is the same as from D to the distal surface of the second molar. P to P through Z forms another equilateral triangle, giving the wisdom-tooth's place in the arch.

"The arrangement of L and J on the left shows the teeth in the act of mastication, while on the right the inner cusp of molars of the upper and outer of the lower molars come in contact when not in use. There is double the surface touching at every lateral movement."

CHAPTER VII.

GENERAL ANATOMY OF THE HUMAN TEETH.

I. The *sockets* of the teeth are made up of a thin layer of cortical bone, distinctly lamellated, and blending with trabeculæ of the cancellous bone in the central part of the alveolar process. The latter we find filled with freely vascularized medullary tissue in the juvenile condition; whereas, in advanced age, this tissue is transformed into fat, which, as a rule, is likewise supplied with numerous blood-vessels. The socket-walls are of the greatest possible strength, with the least mass, since a hollow cylinder is stronger than a solid one. The blood-vessels of the medullary spaces are continuous with those of the periosteum, pericementum, and gums. This explains why sockets easily become necrotic after suppurative periostitis and pericementitis, in event of which maladies a certain amount of the socket is deprived of the nourishing material carried to it by the blood-vessels. (See Fig. 23.)

II. The *compact bone of the socket* is covered with a layer of dense connective tissue of broad bundles. This is continuous with another layer of fibrous connective tissue composed of bundles that run obliquely toward the apex of the root of the tooth. The latter tissue bears the name of *pericementum*, *root-membrane*, or *alveolar dental periosteum*. Its bundles are firmly attached to the walls of the socket and the root of the tooth. Thus it becomes comprehensible that the teeth can stand enormous pressure without injury, as in the process of mastication, in the lifting of heavy weights, or in the suspension of the whole body on a rope, by means of the dentures. We furthermore understand why sometimes a portion of the bony structure is carried away upon the extraction of a tooth. At the same time the pericementum gives a considerable degree of elasticity and a limited amount of mobility to the teeth. This explains the presence of facets upon the approximal surfaces of the crowns of teeth in crowded dental arches.

III. Similarly the upper and the lateral portions of the alveolar process are covered by fibrous connective tissue, the *periosteum*, which blends with the dense fibrous connective tissue of the gum, composed of broad and straight interlacing bundles.

This firm cushion, the *gum*, in a normal condition is but scantily supplied with blood-vessels. The superficies of the gum exhibit numerous finger-like elevations, the so-called papillæ,

FIG. 23.

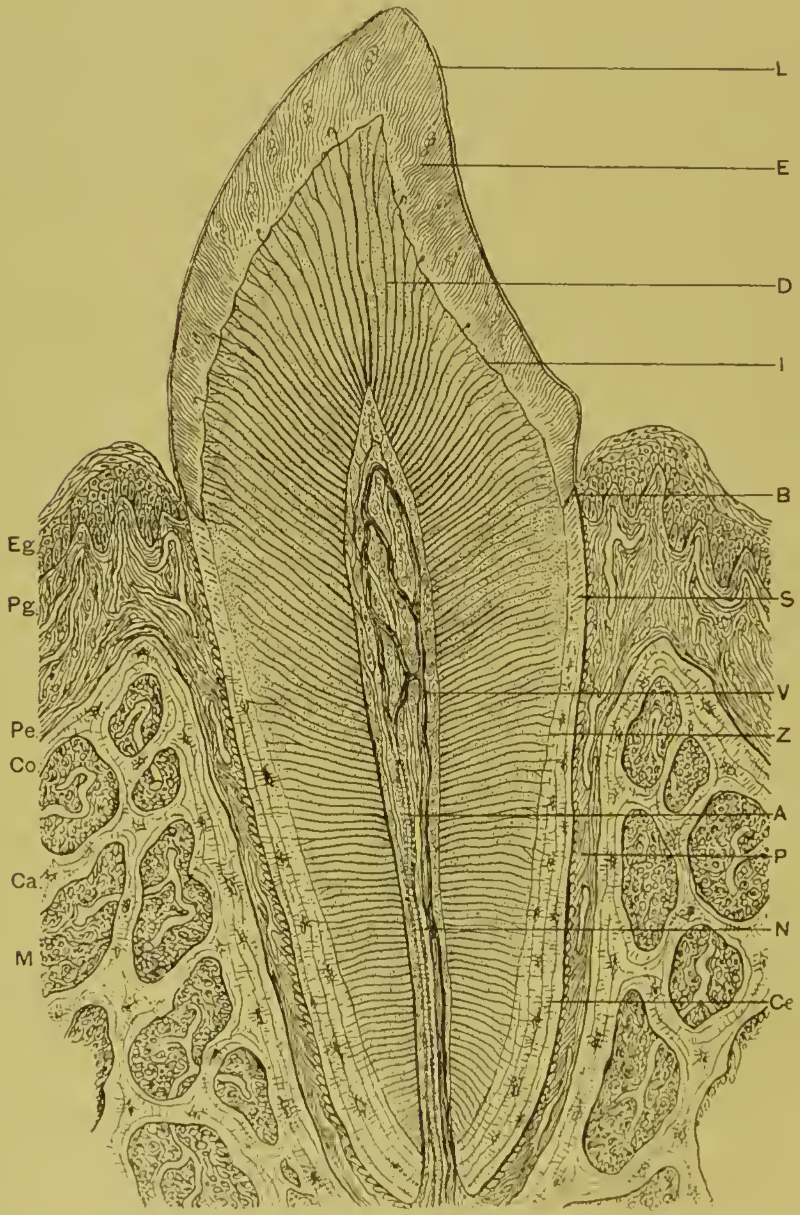


DIAGRAM OF THE STRUCTURE AND IMPLANTATION OF A NORMAL INCISOR TOOTH.

L, cuticle of enamel, Nasmyth's membrane; *E*, enamel; *D*, dentine with uniformly distributed canaliculi; *I*, interzonal layer between enamel and dentine; *B*, border-line between enamel and cementum of neck; *S*, cementum of neck; *Ce*, cementum of root; *Z*, interzonal layer between dentine and cementum; *P*, pericementum; *A*, arteriole of pulp, branching into capillaries; *V*, vein of pulp, taking up capillaries; *N*, medullated nerve-fibers of pulp; *Eg*, stratified epithelium of gum; *Pg*, papillary layer of gum; *Pe*, periosteum; *Co*, cortical bone of alveolus or socket; *Ca*, cancellous bone-tissue of alveolus; *M*, medullary spaces of cancellous bone.

which contain loops of capillary blood-vessels. The sum-total of the papillæ is termed the *papillary layer*. At its outer surface it is covered with a layer of stratified epithelia. In the strata we observe three forms of epithelia, as in the skin and in the mucous membranes generally. The innermost layer is made up of a single row of columnar epithelia, much elongated in a vertical direction and resting upon the connective tissue. This row of columnar epithelia is covered by several rows of cuboidal epithelia, so termed on account of their shape. The layers of cuboidal epithelia are coated by several strata of flat or pavement-epithelia, so called because their length and width are much greater than is their thickness. The pavement layer is composed of a horny substance, and it exhibits properties of life only in the nuclei of the epithelia, the same being the case throughout the flat epithelial covering of the oral cavity. The surface of the gum appears to the naked eye either smooth or slightly granular, since the papillary elevations of the connective tissue and the valleys between them are but slightly pronounced upon the epithelial surface. Continued irritation, as in the too frequent application of the tooth-brush, is, in many instances, sufficient to give the surface of the gums a more or less pronounced papillary aspect.

IV. *Dentine* is the tissue which composes the main mass of the tooth. It consists of a glue-yielding basis-substance (not cartilaginous, as is often stated), richly infiltrated with lime-salts. The chemical constituents, according to Bibra,* of perfectly dried dentine are.—

Organic matter (tooth-cartilage)	27.61
Fat	0.40
Phosph. fluoride calcium	66.72
Carbonate of calcium	3.36
Phosphate of magnesium	1.08
Other salts	0.83

The basis-substance is traversed by the *dentinal canaliculi*, which take their general course from the pulp-chamber toward the summit of the crown, running horizontally in the neck, and in a portion of the root. It is only near the apex that the canaliculi are inclined toward the end of the root. Each canaliculus curves in the general shape of the letter S, slightly toward the pulp-chamber and abruptly toward the periphery of the dentine. In the region of the crown, upon approaching the periphery of the dentine, almost without exception, the canaliculi divide into two or three branches, this branching being termed *bifurcation.* In the region of the neck such a bifurcation of the dentinal canaliculi is exceptional. It is a peculiarity there that the canaliculi do not reach the periphery of the dentine, but stop short of the latter at a distance varying in different teeth, whereas in the root bifurcation is of frequent occurrence.

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* From Tomes's "Dental Anatomy."

Each dentinal canaliculus contains a slightly beaded fiber, the *dentinal fibrilla*, or, in honor of the discoverer, *J. Tomes's fiber.*

In the crown the dentine is surrounded by the enamel, and in the regions of the neck and root by the cementum. The border-line between these tissues has been termed by W. H. Atkinson *the interzonal layer.* This layer has been also termed *the granular layer* by J. Tomes. It is usually marked by shallow excavations along the periphery of the dentine. Occasionally the ultimate branches of some dentinal canaliculi transgress the interzonal layer, producing either loops or club-shaped enlargements in the adjacent portion of the enamel. The interzonal layer between the dentine of the root and the adjacent cementum may be marked by shallow excavations similar to those in the dentine of the crown, or there may exist no distinct boundary line between the two tissues.

V. *Enamel.* Whereas dentine is undoubtedly a form of connective tissue closely allied to bone, enamel bears no resemblance to any other tissue in the animal organism. It starts from epithelium, becomes transformed into connective tissue, yet exhibits features characteristic of epithelial structures. The enamel covers only the crown of a tooth. It is thickest upon the summit of the crown, gradually becoming thinner toward the region of the neck, where it terminates in a sloping line, slightly overlapped by the cementum. The enamel is composed of so-called *enamel-prisms*, exhibiting transverse striations, *the striæ of Retzius.* Between these enamel-prisms there are narrow interstices which hold delicate beaded fibers, the *enamel-fibrillæ.* The enamel-prisms run a wavy course, and we meet with transverse sections intermixed with longitudinal ones so frequently that the idea of interlacing bundles of enamel-prisms forced itself upon previous investigators. Frank Abbott was the first to assert that no such interlacing occurs, and that the appearance of transverse sections intermixed with longitudinal ones is due to the pronouncedly wavy course of some of the bundles, being cut both longitudinally and transversely.

The outer surface of the enamel is covered by a thin, horny layer of epithelial tissue, the so-called *Nasmyth's membrane*, or *enamel-cuticle.* This layer can be rendered visible by the application of strong chemical agents, and is present only in teeth not as yet worn off by mastication. It is in direct union with the outermost epithelial layer of the gum, which is likewise composed of flat, hornified epithelia, to a varying degree. The enamel-cuticle is, therefore, the only layer which closes up the fissure between the neck of the tooth and the adjacent gum.

VI. *Cementum.* This is a stratum of bone-tissue covering the dentine of the root of the tooth. It starts in an oblique line at the neck, gradually increasing in thickness toward the apex, where it borders upon the beginning of the root-canal. The cementum is, as a rule, covered at its outer periphery by a single layer of calcified protoplasmic bodies, similar to the so-called *osteoblasts* (Gegenbaur), which are in connection with the fibrous connective tissue of the pericementum. At the neck it is composed of a calcified basis-substance, pierced by spindle-shaped protoplasmic bodies. In the root portion of the cementum we observe a distinct lamellation, and here we meet with numerous branching protoplasmic bodies, the *cement-corpuscles*, bearing a close resemblance to bone-corpuscles. Even in low amplifications by the microscope we frequently notice a union of the ends of the dentinal canaliculi, with offshoots of cement-corpuscles. From these facts we may infer that each root of a tooth represents a large Haversian system, in which the Haversian canal corresponds to the central pulp-canal and its soft tenants, whereas the outermost layer of the cementum represents the concentrically lamellated cortex. Between these two layers is inserted a broad layer of dentine, traversed by dentinal canaliculi, which we may consider as elongated offshoots of bone-corpuscles. If viewed in this light, dentine may justly be considered a modified bone-tissue, peculiar to the structure of the teeth.

VII. *The Pulp.* The central cavity is called *pulp-chamber* in the crown, and *root-canal* in the root of a tooth. It is filled with a myxomatous connective tissue, in which are distributed blood-vessels and nerves. These enter the pulp-canal at the apex of the root of the tooth. At about the middle of the root-canal a small afferent artery, the *arteriole*, splits up into capillaries, producing throughout the pulp-tissue a rich net-work, terminating at the summit of the coronal portion in loops. The capillaries coalesce with the vein. This vein is a branch of the alveolar vein, into which it carries the blood through the root-canals. There is a large number of bundles of nerves in the pulp, entering the apical foramen in the shape of medullated nerve-fibers. Upon approaching the periphery of the pulp they lose their medullary sheaths and become non-medullated, as is the rule with all medullated nerve-fibers in peripheral organs. During the development of the tooth, the outer surface of the pulp exhibits a row of large protoplasmic bodies, the so-called *odontoblasts* (J. Tomes), which are in direct connection with the tenants of the dentinal canaliculi. In the fully-developed tooth the odontoblasts are not always present, being mostly replaced by irregular rows of medullary corpuscles. The ultimate termination of the nerve-fibrillæ can be traced between these medullary corpuscles or odontoblasts, but never to a direct union with the dentinal fibers. This fact sufficiently proves that the dentinal fibers are not true nerves. Lymph-vessels are unquestionably present in the pulp, but nothing positive has as yet been ascertained as to their course and origin.

Anomalous though not Pathological Formations in the Teeth (see Fig. 24).—Among the most frequent occurrences of such formations, we notice in the crown of the tooth fields filled with a non-calcified basis-substance. They are known as the *interglobular spaces of Czermak.* They appear as irregular spots, varying in size and shape, but always bordered by concave contours. These so-called spaces occur *near*, though never directly *at*, the periphery of the dentine toward the enamel, and occasionally blend with much smaller spaces at the interzonal layer of the neck, or even the root of the tooth. They are traversed by the dentinal canaliculi without the slightest deviation of the latter.

Of common occurrence in the dentine are fields of calcified basis-substance, lacking dentinal canaliculi. Much rarer are parallel striations of the dentine, indicative of the successive formation of the layers of this tissue.

In the enamel at the interzonal layer we not infrequently meet with globular or club-shaped spaces filled with protoplasm. In the highest expression of this abnormality we find every branch of the dentinal canaliculi to have a club-shaped termination. Pigmentation and stratification of the enamel are not rare. J. Retzius first drew attention to their presence. The brown pigmentation of the enamel always is most pronounced

FIG. 24.

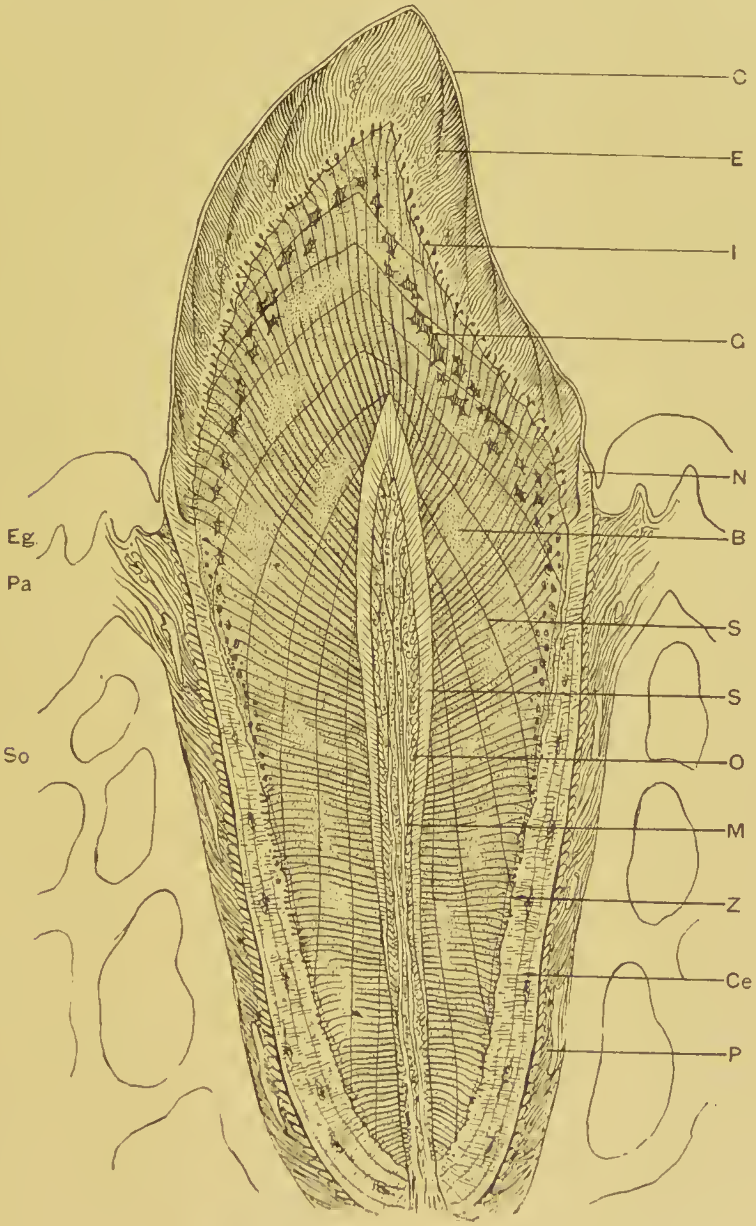


DIAGRAM OF AN ANOMALOUS THOUGH NOT PATHOLOGICAL INCISOR TOOTH.

C, cuticle of enamel, Nasmyth's membrane; *E*, stratified and pigmented enamel; *I*, interzonal layer between enamel and dentine, with club-like terminations of dentinal canaliculi; *G*, dentine with interglobular spaces along the outer periphery; *N*, cementum of neck, overlapping the enamel; *B*, basis-substance of dentine, destitute of canaliculi; *S* (upper), stratification of dentine; *S* (lower), secondary dentine; *Z*, interzonal layer between dentine and cementum, with club-like enlargements of the canaliculi; *Ce*, cementum of root; *P*, pericementum; *O*, row of odontoblasts at the outer periphery of the pulp; *M*, medullated nerves of the pulp; *Eg*, stratified epithelium of gum; *Pa*, papillary layer of gum; *So*, socket or alveolus.

along the periphery and along the striæ of the enamel. What the cause of such pigmentations and stratifications may be, we do not know.

In rare instances the cement of the neck considerably overlaps the enamel. This feature explains certain occurrences in the process of absorption of temporary teeth. Along the interzonal layer between the dentine and the cementum we occasionally meet with club-shaped spaces filled with protoplasm, and in union with the terminations of the dentinal canaliculi. All these features, including the interglobular spaces, may be considered as the result of an imperfect calcification during the process of development.

CHAPTER VIII.

GENERAL HISTOLOGY.

The animal body is built up of four main varieties of tissue, viz:

I. *Connective Tissue.*
II. *Muscle-Tissue.*
III. *Nerve-Tissue.*
IV. *Epithelial Tissue.*

According to the views of most histologists, both the connective and muscle tissues are products of the mesoblast, the middle layer of the germ, and the nerve-tissue originates from the epiblast, whereas the epithelium arises from both the epi- and the hypoblast. This view, however, cannot be strictly adhered to, since we know that the central nerve-organs, though originally products of the epiblast, in further development are composed of a tissue of their own, closely allied to connective tissue. The enamel of the teeth is of an epiblastic or epithelial origin, but during further development it changes to a type of connective tissue.

I. Connective Tissue.—This tissue composes the main mass of the organism. It forms the bony frame or skeleton, the articular surfaces of the joints, or cartilages. As the derma of the skin, it covers the body; as perimysium and perineurium, it accompanies the muscles and nerves: and as periosteum, it envelops all bones. Fat is likewise a sub-variety of connective tissue. The latter is the only tissue serving as a carrier of both blood- and lymph-vessels.

Up to the year 1873, connective tissue was believed to be made up of cells,—the so-called connective-tissue corpuscles,—and an apparently inert intercellular or basis-substance, varying considerably in consistency and chemical constitution. This basis-substance generally is termed glue, a nitrogenous matter for which there exists as yet no chemical formula. Until that time, also, the cells were believed to be isolated individuals, imbedded in cavities of the basis-substance. In the year mentioned, Carl Heitzmann showed that protoplasm in general possesses a reticular structure, a fact which has since been proved by photomicrography. In the basis-substance Heitzmann likewise has shown the existence of a reticulum identical with that of the protoplasm, a fact not as yet generally accepted by histologists. The reticulum, its points of intersection, the granules, and the nucleus are the living or contractile matter proper, and it is this which pervades the basis-substance, as well as the protoplasm. In this view both the animal and the vegetable organisms are a continuous net-work of living matter,—a delicate reticulum, the meshes of which are filled with a lifeless nitrogenous liquid in the protoplasm, while in all varieties of basis-substance these meshes contain a solid or semi-solid nitrogenous matter.

We distinguish four varieties of connective tissue, viz:

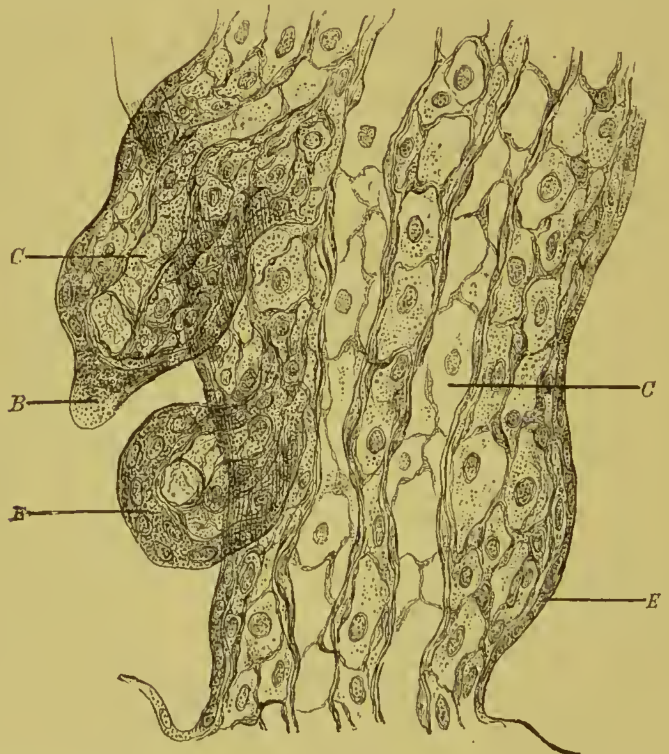
A. *Myxomatous, or mucoid.*
B. *Fibrous, or striated.*
C. *Cartilaginous, or chondrogenous.*
D. *Osseous, or bony.*

Under the last head belong the dentine and the cementum of the teeth. While the character of any variety of connective tissue is exclusively defined by the peculiarities of its basis-substance, it is to be understood that its corpuscles, though varying in size, shape, and arrangement, are made up everywhere simply of protoplasm, or, as in dentine, of fibers of living matter alone.

A. *Myxomatous, or Mucoid Tissue,* is the earliest formation in the embryo, and all varieties of connective tissue are of myxomatous origin. This tissue shows fields of basis-substance corresponding in size and shape to medullary corpuscles, or protoplasmic bodies, which have been transformed into a jelly-like mass, though their minute structure has remained unchanged.

The reticular myxomatous tissue is composed of branching protoplasmic bodies, the meshes of which hold a gelatinous (myxomatous) basis-substance with central nuclei, the remnants of previous protoplasmic bodies. (See Fig. 25.) To this type belong the tissue of the placenta, the umbilical cord, the lymph-ganglia, the so-called adenoid layers and follicles of the mucous membranes, and the pulps of the teeth. Fat is a variety of myxomatous tissue held as a basis-substance in a protoplasmic net-work.

FIG. 25.

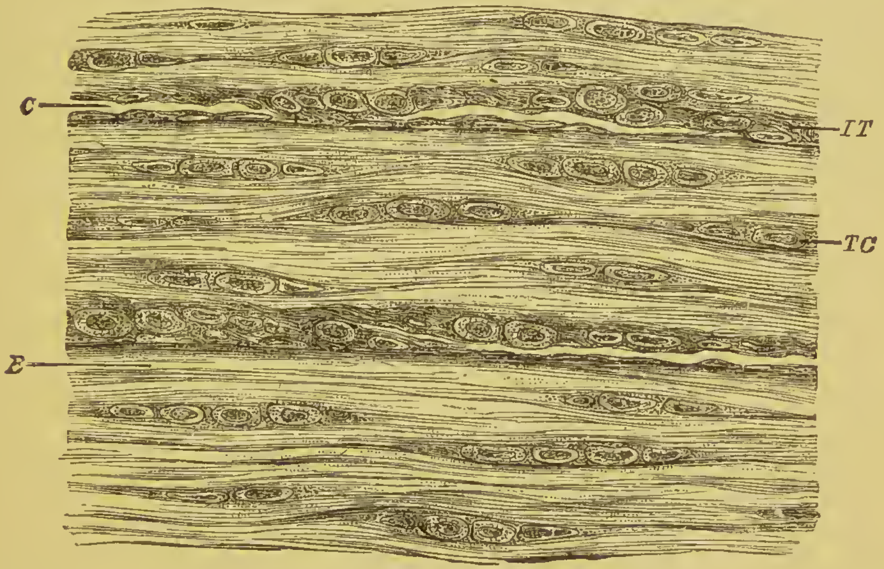


RETICULAR MYXOMATOUS TISSUE OF A VILLUS OF THE PLACENTA OF A HUMAN EMBRYO, FOUR MONTHS OLD. (FROM C. HEITZMANN.)

E, E, epithelial cover of the villus; *B,* solid bud of a growing villus; *C, C,* capillary blood-vessels, overlapped by the myxomatous reticulum. Magnified 500 diameters.

B. *Fibrous, or Striated Tissue,* derives its name from the striated appearance of the basis-substance, which upon being torn asunder has the aspect of fibrillæ. The bundles of such fibers may be thin and arranged loosely, as in the so-called *areolar* variety of connective tissue (pia mater, arachnoid, and peritoneum), or they may be densely put together and traversed by large branching protoplasmic bodies. The bundles are either arranged perfectly parallel, as we observe in the tendon (see Fig. 26), or interlacing and interwoven in all directions, as we find them in the derma of the skin, the periosteum, the perichondrium, the articular and the interarticular ligaments, etc.

Fig. 26.



TENDON OF ACHILLES OF A YOUNG PERSON. LONGITUDINAL SECTION. CHROMIC ACID SPECIMEN. (FROM C. HEITZMANN.)

B, bundles of striated connective tissue, here and there finely dotted; *TC*, tendon corpuscles within the bundles or between the smallest bundles; *IT*, interstitial medullary tissue carrying capillary blood-vessels, *C*. Magnified 500 diameters.

C. *Cartilaginous, or Chondrogenous Tissue*, is composed of protoplasmic bodies imbedded in a dense and tough basis-substance. (See Fig. 27.) In the juvenile condition it is traversed by medullary spaces containing blood-vessels. The existence of connections between the protoplasmic bodies, as well as of the reticulum in the basis-substance, was proven by the method of staining with a solution of chloride of gold and treatment with absolute alcohol.

There are three varieties of this tissue, viz:

The Hyaline Cartilage.

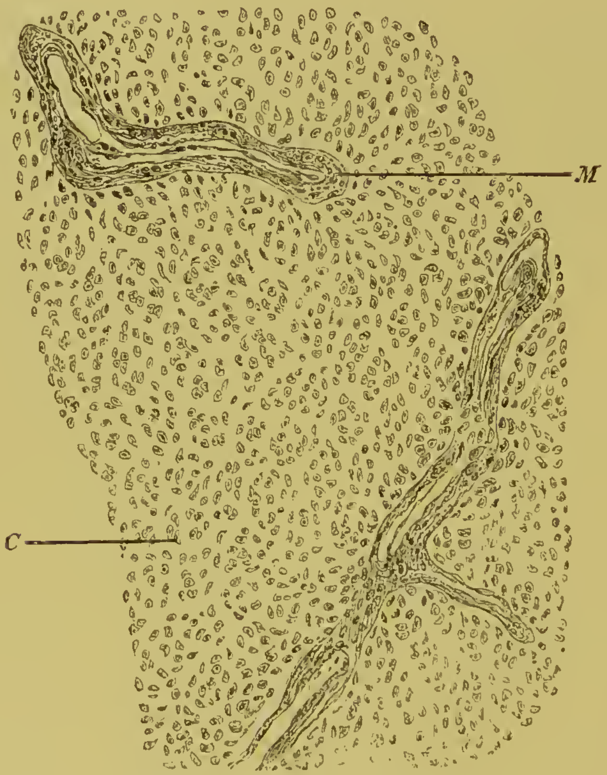
The Fibrous Cartilage.

The Reticular Cartilage.

D. *Bony or Osseous Tissue.*—Of this there are two main varieties, viz: *The cancellous, epiphyseal, or spongy*, and *the compact, or cortical, bone-tissue.*

Cancellous bone is the first bone formed in the embryo, long before the cortical bone makes its appearance. (See Fig. 28.) In human beings it is the only variety of bone present up to the fifth, sixth, or even the seventh month of intrauterine development. In dogs, cats, and rabbits, at birth, none but cancellous bone is found in the skeleton. This tissue consists of small, interconnected trabeculæ of bone, surrounding and inclosing spaces of medullary or myxomatous tissue, supplied with capillary blood-vessels. The trabeculæ are faintly lamellated, and hold a number of branching protoplasmic bodies, the bone-corpuscles. The latter have been known only since 1870, and were discovered by S. Stricker. Previous to that date dry bones, ground thin and mounted in Canada balsam, were resorted to for microscopical examination. In such specimens only the spaces holding the protoplasmic bodies and their offshoots, the so-called canaliculi, were visible. To-day we know that not only each lacuna holds a bone-corpuscle, but that every canaliculus

Fig. 27.



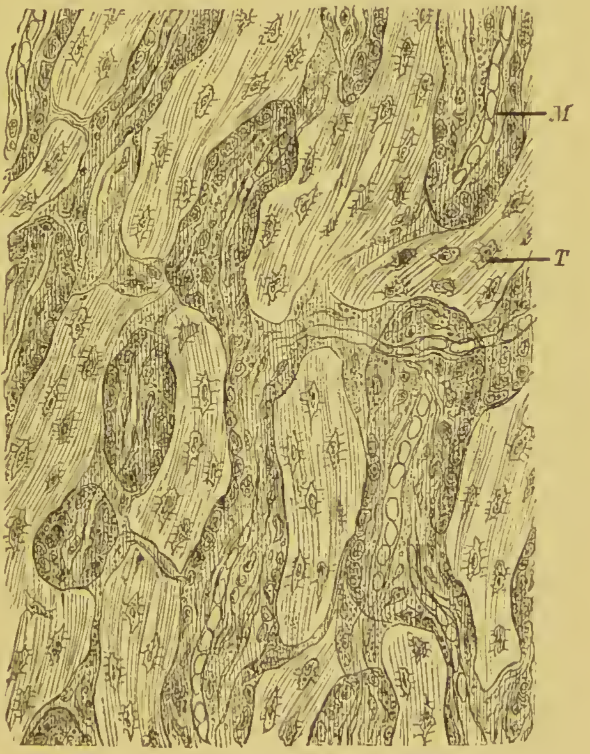
Hyaline Cartilage from the Condyle of Femur of a Newly-born Pup. Chromic Acid Specimen. (From C. Heitzmann.)

C, the tissue of the hyaline cartilage, with scattered groups of cartilage-corpuscles; *M*, medullary spaces, containing blood-vessels and medullary tissue. Magnified 100 diameters.

contains a small fiber of living matter, and the entire basis-substance is traversed by an extremely delicate net-work of such matter, the meshes of which are filled with a glue-yielding basis-substance, saturated with lime-salts.

Cortical bone-tissue is composed of parallel lamellæ, bunched together in the shape of so-called Haversian systems, extending longitudinally with the longitudinal axis of the bones. (See Fig. 29.) The center of each Haversian system is occupied by a medullary canal that holds, besides a straight capillary blood-vessel, a varying amount of medullary tissue. The older the individual, the scantier is this medullary tissue. The lamellated region contains the branching bone-corpuscles, the same as the trabeculæ of cancellous bone. The offshoots of these corpuscles are arranged radiately, interconnecting not only all protoplasmic bodies within the bone, but also the medullary corpuscles, and, indirectly, the walls of the blood-vessels. This is an im-

FIG. 28.

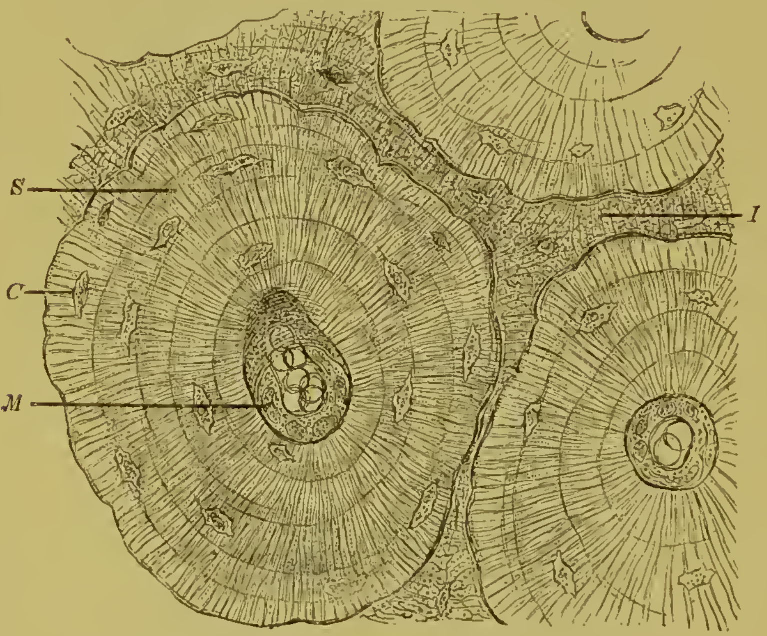


TIBIA OF A NEWLY-BORN PUP. LONGITUDINAL SECTION. CHROMIC ACID SPECIMEN. (FROM C. HEITZMANN.)

T, trabeculæ of bone-tissue containing bone-corpuscles; *M*, medullary spaces filled with medullary tissue, holding blood-vessels in the most central portions. Magnified 200 diameters.

portant fact, since it explains the nutrition of the compact bone, which is sparingly supplied with blood-vessels, though endowed with properties of life. Each large bone, the shaft-bones as well as the lower maxilla, contains in its center a large medullary space traversed by cancellous bone-structure. In youth the medullary spaces hold the so-called red medulla, while in more advanced age they contain fat-tissue. Epiphyseal extremities of bones are mainly cancellous and covered by a thin layer of cortical structure, while articular ends are directly coated with hyaline cartilage.

FIG. 29.



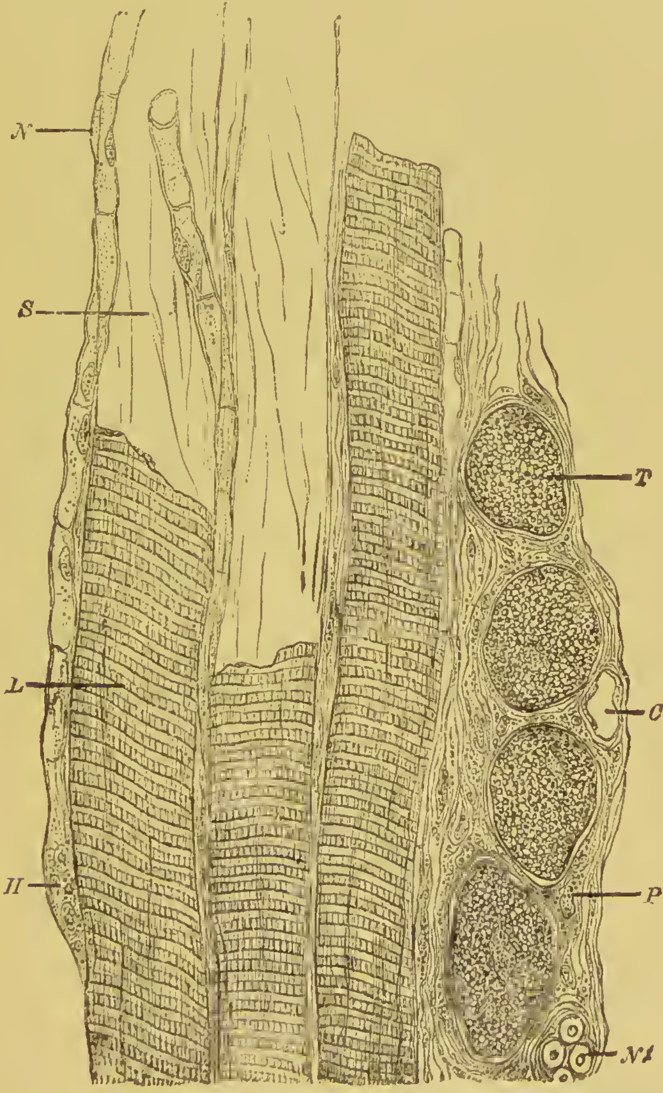
TIBIA OF A GROWN DOG—CORTICAL PORTION, TRANSVERSE SECTION. CHROMIC-ACID SPECIMEN. (FROM C. HEITZMANN.)

S, Haversian system of lamellæ, containing the bone-corpuscles, *C*, with their radiating offshoots; *M*, central medullary, so-called Haversian canal, containing a capillary blood-vessel; *I*, interstitial bone-tissue indistinctly lamellated. Magnified 500 diameters.

II. **Muscle-tissue** is the motor apparatus proper, and occurs in two varieties,—viz, the *smooth or involuntary*, and the *striated or voluntary muscle-tissue*. The former is composed of spindle-shaped protoplasmic bodies, often holding rod-like nuclei in their interior. The contraction of these spindles results in a slow movement of the muscular walls of the cavities of the body, and the larger blood-vessels, arteries, and veins.

The *striated or voluntary muscles* consist of large spindle-shaped fibers, in which there are disks made up of small prismatic pieces, the so-called "sarcous elements." In longitudinal section the disks of the sarcous elements appear in great regularity of arrangement, separated from one another by a slight interstice filled with a liquid. (See Fig. 30.) The shape and arrangement of the sarcous elements greatly vary, depending upon the position of the muscle-fiber at death. Whatever the configuration of the sarcous elements be, they are invariably interconnected by extremely delicate conical threads, both in the longitudinal

FIG. 30.

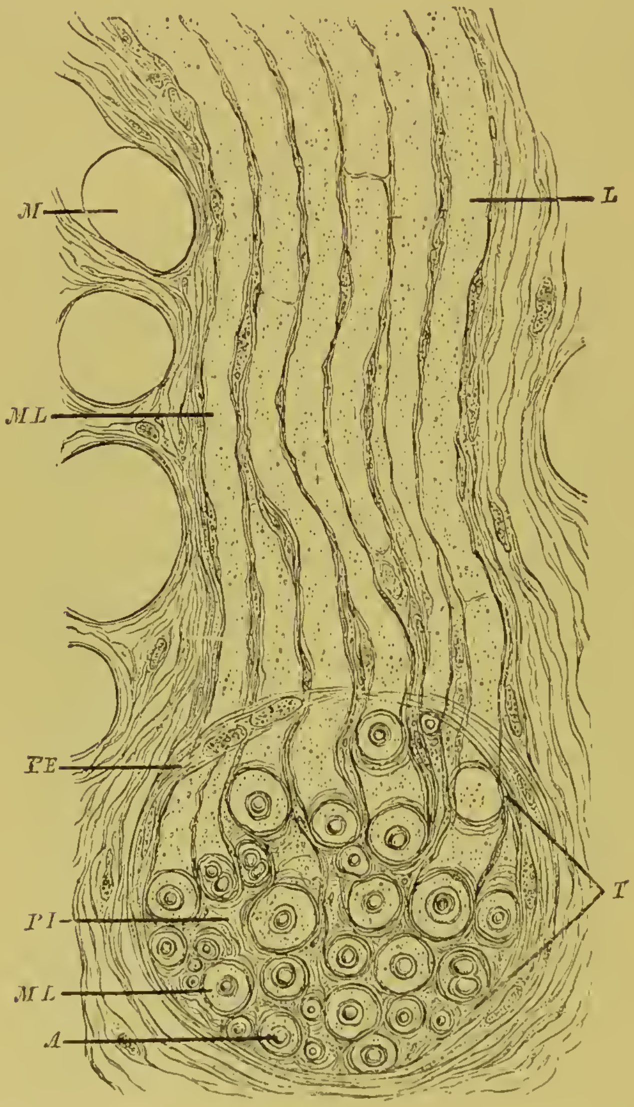


MUSCLE OF TONGUE OF MAN—CHROMIC-ACID SPECIMEN. (FROM C. HEITZMANN.)

L, longitudinal muscle-fiber, broken off and exhibiting its structureless sheath, the sarcolemma, *S*; *N*, medullated nerve-fiber, terminating in the motor hill, *H*; *T*, transverse section of a muscle-fiber; *P*, the perimysium, holding capillary blood-vessels, *C*, and nerves, N^1. Magnified 500 diameters.

and transverse directions. The sarcous elements, like the spindles of the involuntary muscles, are formations of contractile or living matter. The structure of the muscle-fiber is, according to Heitzmann, identical with that of protoplasm.

Fig. 31.



Branch of the Motor Oculi Nerve of Man. (From C. Heitzmann.)

L, longitudinal, *T*, transverse section of the bundle; *PE*, external perineurium; *PI*, internal perineurium; *ML*, myelin investment; *A*, axis-cylinder; *M*, transverse sections of muscle-fibers. Magnified 600 diameters.

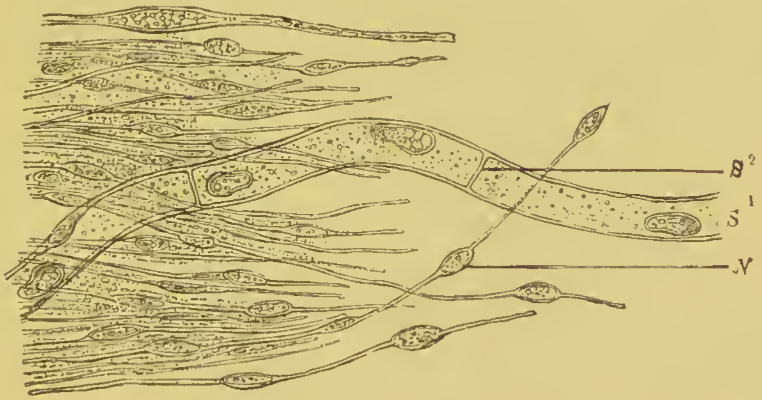
The only difference is that in protoplasm the granules and the points of intersection of the minute reticulum are small and arranged without regularity; whereas in the striated muscle the points of intersection are large and of a prismatic or disklike shape. The contraction of the protoplasm and that of the muscle-fibers are based upon the same principle.

III. Nerve-tissue.—As the writer intends to confine himself to but a brief description of the nerves, he will not dwell upon the central nervous organs, the brain and the spinal cord.

We distinguish two varieties of nerve-fibers,—viz, the *medullated* and the *non-medullated.*

The *medullated nerve-fibers* exhibit to the naked eye a white color, owing to the presence of *myelin*, or *nerve-fat*, which surrounds the central conducting fiber, the so-called *axis-cylinder.* In transverse sections of bundles of medullated nerve-fibers we observe around the periphery of the *bundle* a sheath of delicate fibrous connective tissue, the *external perineurium.* From this layer arise minute offshoots which encircle each nerve-fiber, as the *internal perineurium.* (See Fig. 31.) Next follows a thin layer of nucleated connective tissue, *Schwann's sheath.* After this a layer of myelin or nerve-fat, which surrounds the central axis-cylinder. The latter is enveloped by an extremely thin, flat layer of connective tissue, the *sheath of the axis-cylinder.* The medullated nerve-fibers, upon approaching the surface of the organ, usually lose their myelin-sheaths, and the hitherto undivided axis-cylinder splits up into minute beaded fibrillæ, which directly join the reticulum of the protoplasmic bodies at the periphery.

FIG. 32.



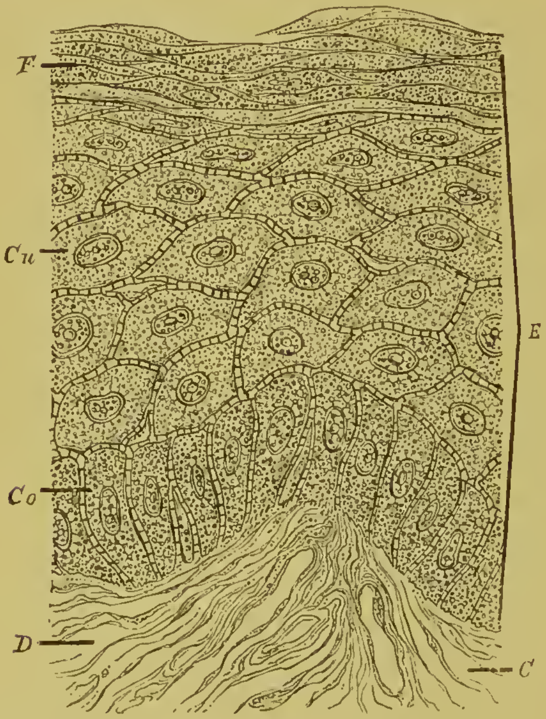
MEDULLATED AND NON-MEDULLATED NERVE-FIBERS FROM THE RETINA OF A BULL. (FROM C. HEITZMANN.)

S^1, myelin sheath, with oblong nuclei and (S^2) transverse septa. The myelin oozed out. N, non-medullated nerve-fibers, with varicose enlargements. Magnified 600 diameters.

The non-medullated nerve-fibers are mere axis-cylinders, lacking the myelin investment, but, as a rule, inclosed by an axis-cylinder sheath. (See Fig. 32.) At the periphery they split up into axis-fibrillæ. The axis-cylinder has a delicate reticular structure, and the axis-fibrillæ are linear projections of the reticulum. The nerve action, probably, is based upon the contraction of this reticulum of living matter. If the contraction runs centripetally, it is termed sensation; if centrifugally, it leads, when connected with muscle-fibers, to motion.

IV. Epithelial Tissue.—The surface of the body,—like all cavities which are in direct or indirect communication with the outer world,—is covered with either a single or a stratified layer of nucleated protoplasmic bodies, the *epithelia*. These formations are separated from one another by a thin stratum of horny cement-substance, chemically different from the glue of the basis-substance of connective tissue. The cement-substance invariably is pierced by delicate conical offshoots of living matter, *Max Schultze's thorns*, interconnecting the epithelial elements. The closed cavities of the body, including those of

FIG. 33.



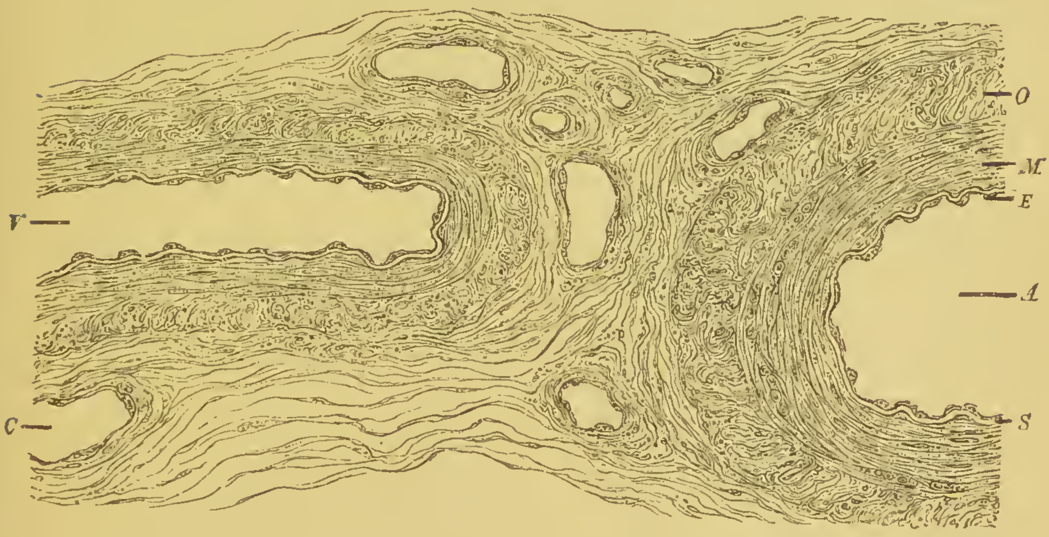
STRATIFIED EPITHELIUM OF THE SKIN, COVERING A MYXOFIBROMA ON THE RIGHT SHOULDER. VERTICAL SECTION. (FROM C. HEITZMANN.)

F, flat epithelia; *Cu*, cuboidal epithelia; *Co*, columnar epithelia, all the three composing the epithelial layer, *E*; *D*, derma of skin, composed of vascularized connective tissue, *C*. Magnified 600 diameters.

the heart, blood-vessels, and lymph-vessels, are lined by endothelia,—flat, protoplasmic bodies, morphologically identical with epithelia.

We distinguish three main varieties of epithelia,—viz, the *flat*, the *cuboidal*, and the *columnar*. The last variety often carries fine moving hairs, the so-called *cilia*. A single layer of epithelium may be constituted of either of the above-named varieties. Stratified epithelia, such as we find on the surface of the skin and on the mucous membrane of the oral cavity, including the gums, are made up of three varieties. The lowest layer—that nearest the connective tissue—is composed of a single row of columnar epithelia; the next, of a number of cuboidal epithelia; and the outermost, of a number of flat epithelia. The latter, on the surface of the skin, are entirely hornified, whereas on the surface of the oral mucous membrane only the protoplasm is hornified, the nucleus being still endowed with properties of life. (See Fig. 33.) The finest terminations of the sensory nerves, the axis-fibrillæ, run in the cement-substance between the epithelia, and there inosculate directly with the thorns, and indirectly with the protoplasmic reticulum, thus rendering all epithelia sensitive.

FIG. 34.



BLOOD-VESSELS FROM THE LOOSE ADVENTITIAL CONNECTIVE TISSUE OF THE SPERMATIC CORD OF MAN. (FROM C. HEITZMANN.)

A, artery, with *E*, endothelial and covering hyaline layer: *M*, smooth muscle layer; *O*, adventitial layer; *V*, vein, exhibiting the same layers as the artery: *C*, capillary blood-vessels, composed of a single endothelial layer, with a surrounding delicate adventitial fibrous connective tissue. Magnified 200 diameters.

Besides protecting the surface of the body, the epithelia have to perform the important duty of secretion. A colony of epithelia is termed a *gland.* We distinguish two varieties of glands,—viz, the *acinous* or *berry-shaped*, and the *tubular*. All the mucous and salivary glands emptying their secretion into the oral cavity are of the acinous variety. Quite frequently, but erroneously, these glands are termed *follicles*, a name that applies to an aggregation of lymph-tissue, and this latter, being a formation of myxomatous connective tissue, never secretes.

All blood-vessels are lined by flat endothelia. The wall of a capillary is made up of endothelia only. The arteries have, besides the endothelia, a more or less heavy middle coat of smooth muscles, and an outer coat, the so-called *adventitia*, composed of fibrous connective tissue. The veins, in structure, resemble the arteries, but have a much less pronounced muscular coat. (See Fig. 34.)

The lymph-vessels are made up of a single layer of endothelia, whereas the larger lymphatics have a middle muscular coat and an outer adventitial one.

CHAPTER IX.

DEVELOPMENT OF CONNECTIVE TISSUE.

To the minds of Schleiden (1837) and Theodore Schwann (1839) the vegetable and animal organisms were composed of cells and their derivations,—viz, intercellular substance. The cell was considered to be an individual, and composed of a vesicle with liquid or semi-liquid contents, and a central nucleus. An organism, it was thought, was built up of millions of such cells. Each cell might originate spontaneously from an albuminous liquid by the formation of, first, the nucleus, and afterward the cell-wall, similar in shape to two watch-glasses held together, and lastly an accumulation of liquid within the vesicle, the cell-wall.

Schwann's views, adopted by the Vienna school, guided by Rokitansky, were overthrown in 1852 by Rudolph Virchow,* who stated that a cell was provided with a wall of its own, held a viscid albuminous liquid, and was itself the seat of life, which it was not considered to be by Schwann nor the Vienna school.

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* "Die Cellularpathologie." Berlin, 1871.

Virchow held and still holds the view that the organism is composed of a large number of individual cells, separated from one another by an intercellular substance, which he considers to be a product of secretion on the part of the cell. He, however, acknowledged one variety of interconnected cells, termed star-shaped or stellate, such as we know to exist in the myxomatous tissue. (See Fig. 35.)

FIG. 35.

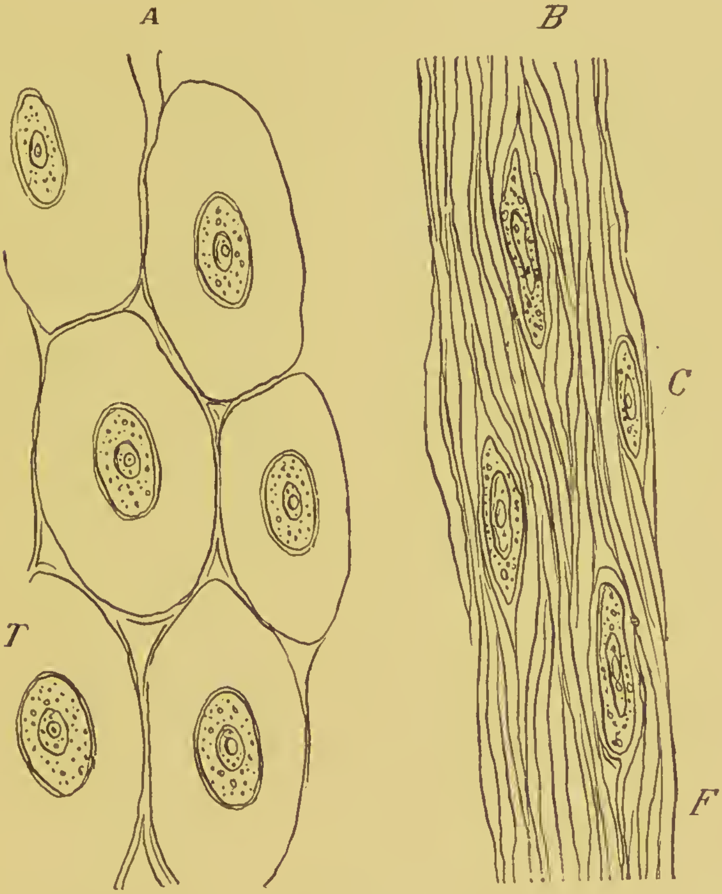

DIAGRAM OF THE STRUCTURE OF CONNECTIVE TISSUE, ACCORDING TO R. VIRCHOW (1852).

A, *structure and development of reticular cartilage.*—*T*, territory of the cell, called intercellular substance, considered inert and a product of secretion of the cell. **B**, *structure and development of fibrous connective tissue.*—*C*, nucleated cell, lying in a cavity; *F*, fibers around the cell, considered inert glue and a product of secretion of the cells.

In 1861, Max Schultze,* of Bonn, Germany, announced novel views in regard to the construction of cells. He denied the existence of a cell-wall, and said that a cell is a lump of protoplasm holding granules and a nucleus, endowed with the properties of life. The word "protoplasm" was accepted by him from the botanist, Hugo von Mohl, who, several years before, had applied this term to the contents of vegetable cells. In England, L. S. Beale* almost simultaneously announced similar views, applying the term "bioplasma" to the substance which builds up the cells. This bioplasma was the true living or germinal matter, whereas all intercellular substances he considered as inert or formed material. Unfortunately, he was led to term the muscles and nerves "formed material" also, and yet these tissues are known to be the most active of the organism. It is

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* *Muller's Archiv*, 1861.

FIG. 36.

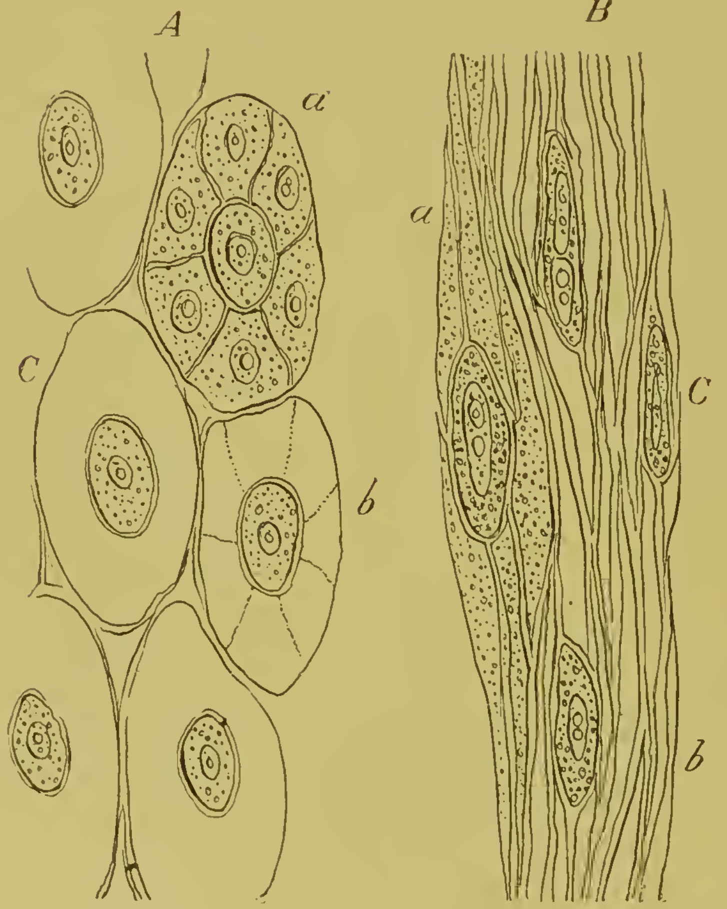

DIAGRAM OF THE STRUCTURE OF CONNECTIVE TISSUE, ACCORDING TO MAX SCHULTZE (1861).

A, *structure and development of reticular cartilage.*—*a*, territory originally composed of a number of embryonal corpuscles,—protoplasm; *b*, peripheral protoplasmic bodies transformed into inert glue-yielding basis-substance, the central protoplasmic body left unchanged,—cartilage-cell; *c*, fully-developed territory. **B**, *structure and development of fibrous connective tissue.*—*a*, elongated protoplasmic bodies around the central cell; *b*, fibrous basis-substance, the product of a chemical transformation of protoplasm; *c*, unchanged granular and nucleated protoplasm, the connective-tissue cell.

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* "On the Structure and Growth of the Tissues." London, 1865.

for this reason that Beale's views have attracted but little attention.

Max Schultze's assertions did not directly affect the cell-doctrine, although he admitted that the term "cell" had lost its significance, and that it should be applied only in honor of its discoverers, Schleiden and Schwann. M. Schultze at the same time propounded, concerning the origin of the intercellular substance, new views which must be understood in order to trace the development of the modern researches in the process of inflammation. In the opinion of Virchow, intercellular substances were merely a secretory product of the cells, whereas Max Schultze proved that these substances are derivations of protoplasm. According to Schultze, a number of protoplasmic bodies become chemically transformed into basis-substance, and thus they are rendered inert and dead. (See Fig. 36.) Beale's doctrine was different, since he said that an originally large mass of bioplasma is converted at the periphery into formed material, and only the central portion remains, as forming or germinal matter.

Soon afterward, E. Brücke, of Vienna, asserted that neither were the granules nor was the nucleus an essential feature of a cell, and consequently he defined the cell as a structureless lump of protoplasm, intrinsically destitute of granules and a nucleus. The expression "structureless" indicated not necessarily that a structure was absent, but that it could not be made out with the microscope. He likewise admitted that a lump of protoplasm is the real seat of life, and is able to produce new lumps—*i.e.*, new cells—by proliferation and division, in normal development of the tissues as well as in morbid processes.

In 1873, Carl Heitzmann, at that time in Vienna, published a series of articles in the Vienna Academy of Sciences,* exploiting yet further entirely novel discoveries concerning the structure of protoplasm, and the structure and origin of the basis-substance.

Heitzmann maintains that a cell, or a lump of protoplasm, hitherto considered structureless, is indeed possessed of a pronounced reticular structure. Since he had seen this reticulum in continuous change of place and shape during the locomotions of living protoplasmic lumps, such as amœbæ, colorless blood-corpuscles, etc., he called the substance which builds up the reticulum the living or the "contractile matter" proper. He designates as formations of living matter the nucleus, the granules, with their interconnecting threads, and an extremely thin layer, inclosing the lump of protoplasm all around. At first the existence of the reticulum was denied by most observers, and afterward, when they could not any longer deny it, they said that it was not originally observed by Heitzmann, but was discovered by C. Frommann in 1867. Frommann, it is true, speaks of a reticulum in connective tissue, and in ganglionic cells, but with-

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* *Sitzungsberichte der Wiener Akademie der Wissenschaften*, 1873

Fig. 37.

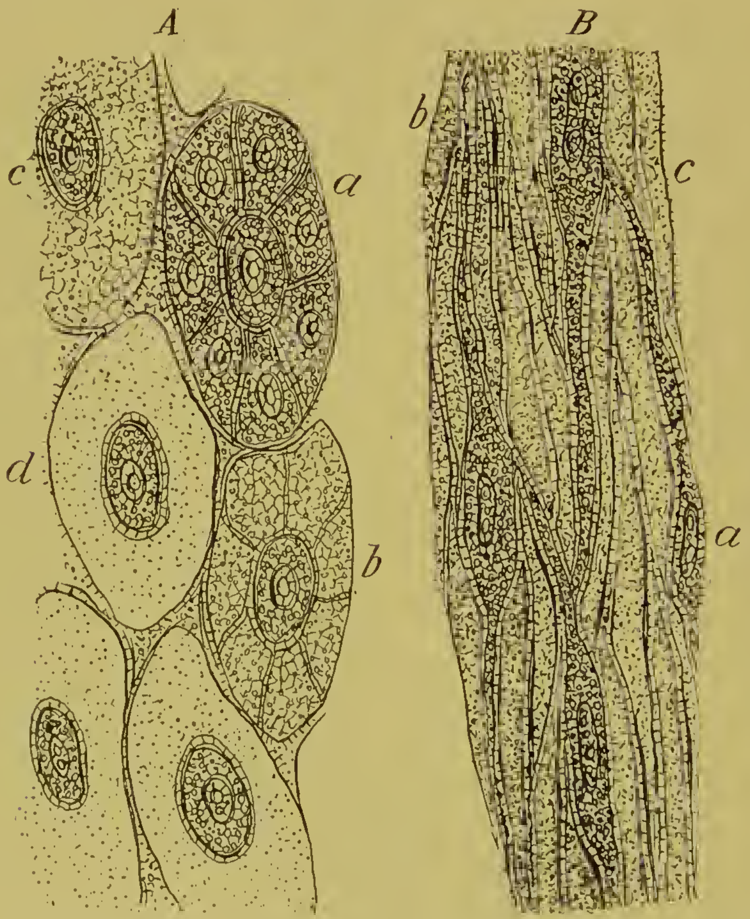

Diagram of the Structure of Connective Tissue, according to C. Heitzmann (1873).

A, *structure and development of reticular cartilage.*—*a*, territory originally composed of a number of embryonal corpuscles,—protoplasm containing a reticulum of living matter; *b*, peripheral protoplasmic bodies in the beginning infiltration with glue-yielding basis-substance, the chemical change taking place in the fluid, filling the meshes of the reticulum; the central protoplasmic body left unchanged,—cartilage-corpuscle; *c*, infiltration with basis-substance further advanced; *d*, infiltration with basis-substance accomplished, the reticulum present, but rendered invisible. **B**, *structure and development of fibrous connective tissue.*—*a*, branching and interconnecting protoplasmic tracts; *b*, fibers composed of protoplasmic spindles, holding the reticulum of living matter, all interconnected by living matter; *c*, advanced infiltration with basis-substance, the reticulum present, but rendered invisible.

out giving an illustration thereof. He afterward declared that he had never used lenses of a higher power than 450 diameters. To observe the reticulum in the protoplasm with such a power of the microscope is simply impossible, even to an experienced eye. Indeed, from 800 to 1000 diameters are required for the study of the reticulum under consideration. That the reticulum exists is to-day a settled fact, the more so as Stricker, in 1890, succeeded in reproducing it by photography, magnifying a living colorless blood-corpuscle of the proteus by means of the electric microscope, with a power of 2500 diameters.* In this photomicrograph the reticulum in the protoplasm is exactly the same as discovered and described by Carl Heitzmann in 1873.

That the nucleus is made up of living matter became apparently doubtful when, in 1875, the so-called karyokinesis of the nucleus was discovered by Strassburger, Bütschli, Flemming, and others. It was shown that the nucleus is composed of loop-like threads representing stars and double-stars preceding its division. Since these loops could be stained deeper by certain anilin dyes, especially safranin, than the granules of the protoplasm, it was asserted that the nucleus is composed of a substance of its own, called "nuclein" and "chromatin." It is plain that a substance capable of changing its shape and place must be living matter. The karyokinetic threads assumed a deeper color only on account of their being more bulky than the rest of the reticulum in the surrounding protoplasm. Besides, it was shown that even at the height of karyokinesis, the loops remain interconnected with the surrounding reticulum of the protoplasm, which again proves their identity. Not only do all movements occur in consequence of contraction and extension of the reticulum, but all new formations and outgrowths start from this substance, respectively from the granules, the points of intersection of the reticulum. This again proves that the reticulum is the living matter proper, in the meshes of which there exists a liquid holding nitrogen, but, being a liquid, not endowed with the properties of life.

Originally every so-called cell is a solid granule of living matter, which in turn becomes vacuoled by an accumulation of liquid, and, at last, is reticulated, in consequence of perforations of the walls of the vacuoles.

Another discovery of Carl Heitzmann, in 1873, was that the intercellular or basis-substance of the connective tissue is not dead or inert, as hitherto supposed, but is alive in the same sense as the cells themselves. The reticulum of living matter visible in the latter is present also in the basis-substance, though rendered invisible by chemical changes and a solidification of the originally liquid contents of the meshes in the protoplasm. It has been proven that in all varieties of connective tissue, in the muscles, the nerves, and the epithelia, the so-called cells are interconnected by means of delicate threads of living matter, or indirectly by the reticulum pervading the basis-substance. (See Fig. 37.)

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* *Arbeiten aus dem Institute für experimentelle Pathologie*, 1890.

In the development of all varieties of basis-substance, the protoplasm shares, by a process of chemical transformation which renders it more or less firm and solid. It has also been proven that in the formation of basis-substance the protoplasm does not perish altogether, but only the lifeless liquid portion which is held in the meshes of the reticulum becomes solidified, whereas the reticulum itself remains unchanged.

Development of Bone-Tissue.—While all varieties of connective tissue develop directly from indifferent or medullary tissue, bone is a secondary formation, originating either from previous hyaline cartilage or from fibrous connective tissue. The latter is the case with the flat bones of the skull; the former, with all the rest of the skeleton, including the lower jaw and the greater portion of the upper jaw. In both instances the process is identical; indeed, W. X. Sudduth* has shown that even the lower jaw may, in part, develop from fibrous connective tissue, independently of hyaline cartilage. Whenever hyaline cartilage is about to be transformed into bone-tissue, as in the case of the lower jaw in the sixth week of embryonal life, the cartilage becomes reduced to medullary tissue, a process frequently, though not always, preceded by a deposition of lime-salts at the border of the territories of the cartilage-corpuscles. Sometimes, before the cartilage begins to change into embryonal tissue, a calcified frame of basis-substance is produced. In former years, histologists encountered great difficulties in explaining the origin of the medullary tissue. Some of them—A. Rollet, for example—have gone so far as to assert that the cartilage-cells perish altogether, and that into their places colorless blood-corpuscles migrate, giving rise to bone-tissue. To-day all such difficulties have vanished, since we know that not only are the cartilage-corpuscles traversed by a net-work of living matter, but that so also is the dense basis-substance. Nothing is required but a liquefaction of this basis-substance to liberate the reticulum, whereupon the protoplasmic condition of the tissue is re-established. The newly-appearing medullary corpuscles, in this view, are nothing but the result of the return to the embryonic condition of the cartilage-tissue. (See Fig. 38.) This process is

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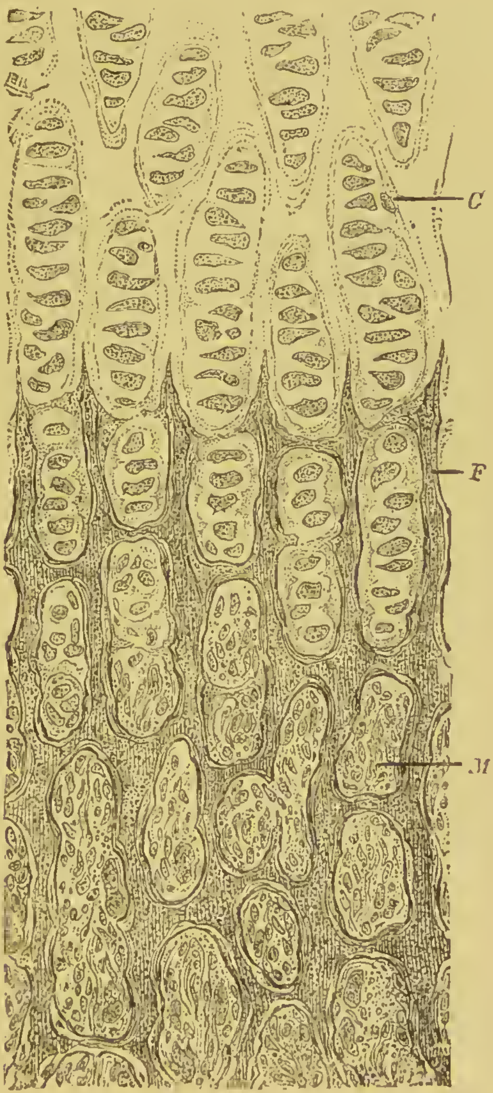
* "The American System of Dentistry," 1886.

FIG. 38.

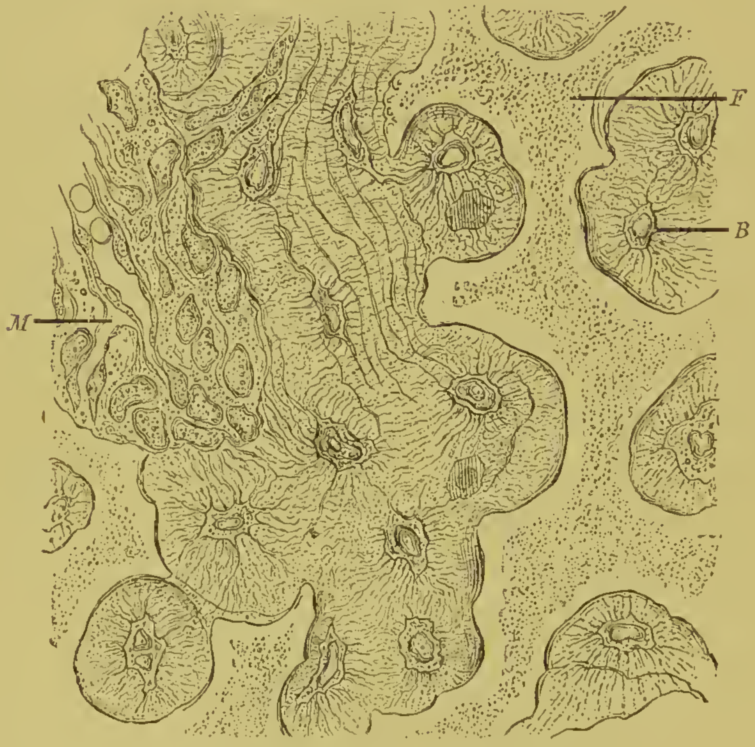


HUMERUS OF A HUMAN EMBRYO, FIVE MONTHS OLD. SAGITTAL SECTION. CHROMIC ACID SPECIMEN. (FROM C. HEITZMANN.)

C, rows of cartilage-corpuscles in elongated groups, due to their territories; *F*, frame of calcified basis-substance, around which, in the lower portions, the first traces of bone-tissue are noticeable; *M*, medullary space, containing medullary corpuscles. Magnified 300 diameters.

followed by an outgrowth of living matter into threads, which afterward, by vacuolation, become hollowed, and thus blood-vessels are formed holding red blood-corpuscles, even before union with the already permeable capillary system. The spaces filled with embryonal or medullary tissue are bordered by the calcified basis-substance of the previous cartilage, this evidently serving as a support of the cartilage, which, to a considerable degree, has been reduced into protoplasm. Around this calcified frame the first-formed territories of bone-tissue are seen, with their convexities lying against the calcified basis-substance. (See Fig. 39.) Later a number of such medullary corpuscles unite, coalescing into globular masses of so-called *myeloplaxes* (Robin), or *giant cells* (Virchow), in which we frequently notice a large number of nuclei placed at nearly regular intervals. (See Fig. 40.)

Fig. 39.

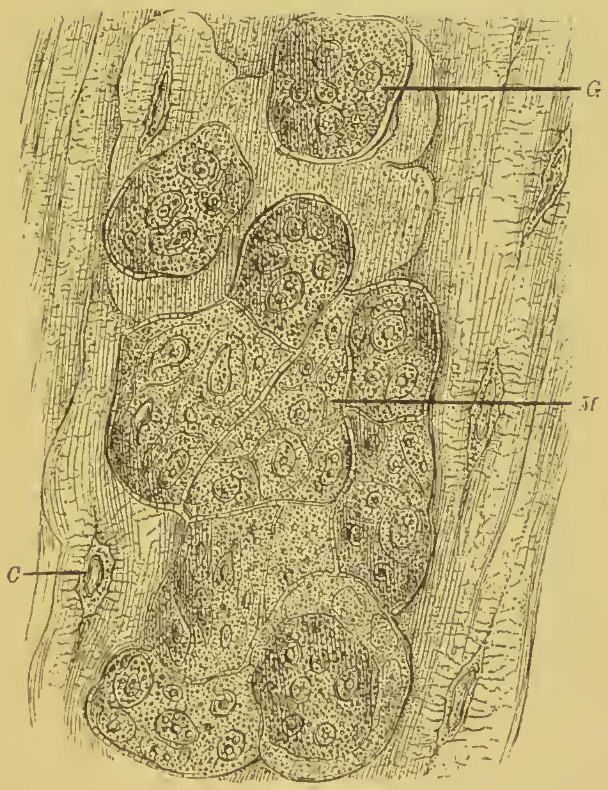


Vertebra of a Human Embyro, Five Months Old. Horizontal Section. Chromic Acid Specimen. (From C. Heitzmann.)

M, medullary space, with central blood-vessels and medullary tissue; *B*, first-formed globular territories, containing one or two central bone-corpuscles, with radiating offshoots. The territories lie against the trabeculæ of the original calcified basis-substance of the cartilage, *F*. Magnified 500 diameters.

Such a globular body is the beginning formation of a territory of future bone-tissue. In the center of the territory a certain amount of protoplasm remains unchanged, representing the future bone-corpuscle, whereas the peripheral portion of the territory becomes infiltrated, first with a glue-yielding basis-substance, and afterward with lime-salts. The latter portion is traversed by radiate protoplasmic offshoots, all of which communicate with the central bone-corpuscle. The formations formerly termed *lacunæ*, therefore, are nothing but the central cavities in the basis-substance, holding the bone-corpuscle. What have been termed *canaliculi* are the offshoots of the central cavities, holding threads of living matter. In fully-developed bone, the bone-corpuscles and their offshoots are quite conspicuous. By decalcification and staining there is rendered visible throughout the whole territory a delicate reticulum of living matter, identical with that seen in the protoplasm itself.

FIG. 40.

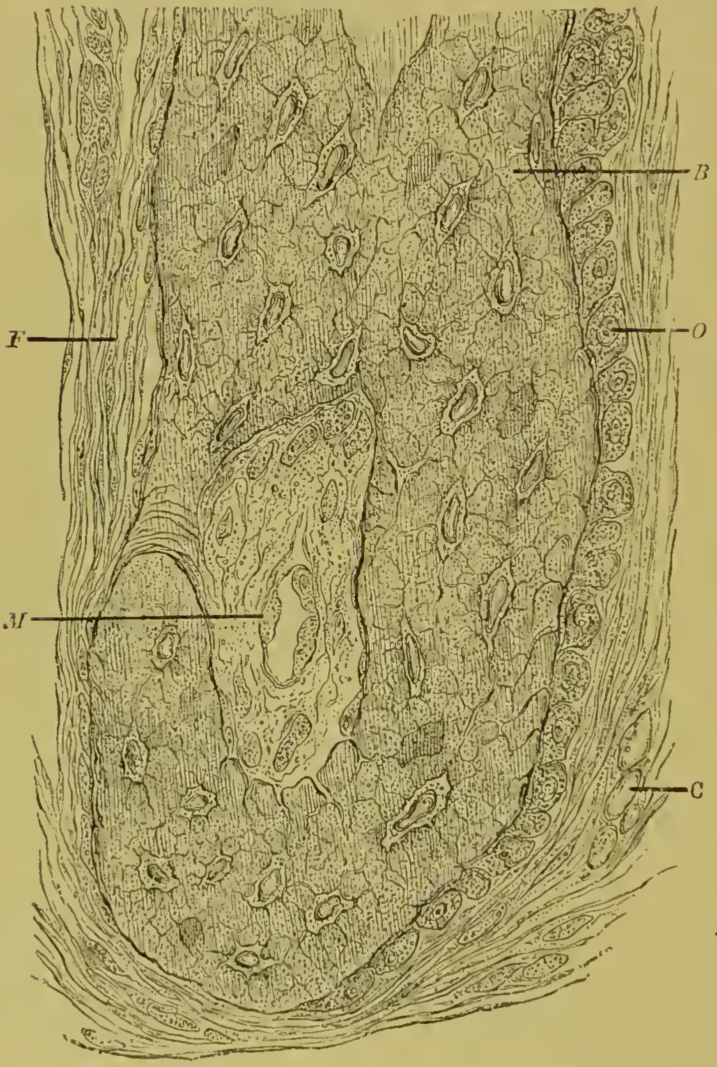


SURFACE OF THE SCAPULA OF A KITTEN. CHROMIC ACID SPECIMEN. (FROM C. HEITZMANN.)

C, lamellated bone, with bone-corpuscles; *G*, a single territory of bone-tissue liquefied, resulting in the formation of a multinuclear plastid or cell; *M*, coalesced masses of multinuclear plastids or cells. Magnified 600 diameters.

Lamellated bone arises by an arrangement in rows of medullary corpuscles adjacent to the already formed bone. The large medullary bodies termed *osteoblasts* are a preceding stage of bone, just as the *odontoblasts* are of dentine, and the *ameloblasts* are of enamel. Either of these bodies, which resemble epithelia, must break up into indifferent corpuscles in order to give rise to permanent bone, dentine, or enamel.

FIG. 41.



SKULL OF HUMAN EMBRYO, FOUR MONTHS OLD. HORIZONTAL SECTION. CHROMIC ACID SPECIMEN. (FROM C. HEITZMANN.)

F, fibrous connective tissue of the pericranium; *M*, medullary space, with central blood-vessel; *B*, first-formed trabecula of bone; *O*, row of osteoblasts; *C*, medullary corpuscles of the inner pericranium, infiltrated with lime-salts. Magnified 500 diameters.

Whenever bone develops from fibrous connective tissue, the latter is first reduced to embryonal tissue in the same manner as

Dental Stude[illegible] Library

hyaline cartilage previous to the formation of bone. The further stages of the production of bone from fibrous tissue are identical with those in the development from hyaline cartilage. (See Fig. 41.)

The law here laid down is but a brief sketch of the history of development as first established in 1873 by Carl Heitzmann. Every tissue originates from protoplasm in the state of indifference,—the so-called *embryonal, or medullary tissue. No tissue can be transformed into another unless it has first been reduced to the embryonal condition.* This law holds good not only in the progressive evolution of the tissues, but also in their retrogressive changes, and in all morbid processes,—*i.e.*, in inflammation or in the formation of new tissue, as the result of an inflammatory process termed "hyperplasia," or in the formation of tumors.

CHAPTER X.

THE MINUTE STRUCTURE OF DENTINE.*

Methods.—The best method in the preparation of bone-tissue for microscopical purposes is doubtless the treatment with chromic-acid solution of the strength of from one-half to one per cent. The same treatment has repeatedly been resorted to by different investigators of tooth-substance. The writer has used this solution extensively for this purpose, adopting precautions suggested by his experience in dealing with bone. These are, to immerse only a few teeth in a large vessel containing a considerable amount of chromic-acid solution; to renew the supply of this every third or fourth day, and to add, to enforce the action of the fluid, very small quantities of dilute hydrochloric acid. Under this treatment the teeth, after a few months, become dark green from the reduction of the chromic acid to the sesquioxide of chromium. This method is most effective for softening teeth, both human and animal, when they are still in the jaw. Wonderful results can be obtained by cutting at the same time bone and tooth prepared in this process: also in preparing specimens from embryos, in order to study the history of development of teeth. This method is highly recommended, although the chromic acid only softens the cement and dentine to a certain depth, so that a tooth kept howsoever long in the chromic-acid solution never is fit to be cut through its whole substance at one time.

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* "The Distribution of Living Matter in Human Dentine, Cement, and Enamel." *Dental Cosmos*, 1878–1879.

The sections so obtained are ready for staining with carmin or hæmatoxylin after they have been immersed in and washed with distilled water, also for staining with chloride of gold, which latter may be done in the following way: Thin sections, after having been washed in distilled water for twenty-four hours and thus freed from the remnants of chromic acid, are to be placed in a solution of chloride of gold of the strength of half of one per cent., by means of glass rods, as metals must be avoided in the treatment with chloride of gold. These sections are to remain in the solution for from half an hour to an hour, and must then be thoroughly washed with distilled water and exposed to daylight for several days, when they are ready for mounting in the ordinary way in chemically-pure glycerin.

The greatest objection to the chromic-acid treatment is that enamel never can be obtained in connection with the dentine. If hydrochloric acid has been used in addition to the chromic-acid solution, the enamel is almost completely dissolved. If chromic acid alone has been used, the enamel becomes so brittle that it crumbles into small particles under the knife. Under such circumstances the outer surface of the dentine looks bay-like, owing to the curved lines on the boundary between the dentine and enamel.

Lactic acid, if diluted sufficiently, so acts upon teeth as to dissolve the lime-salts much faster than chromic acid does. Specimens prepared in this way, however, in the writer's experience, are not distinct enough for study with high powers; hence a tooth, after being softened with lactic acid, has to be immersed in chromic-acid solution for several weeks. But the greatest objection to the use of the lactic-acid solution is the formation of mildew in a relatively short time, and the dissolving of the enamel from the teeth.

The only method which has enabled the writer to obtain specimens of teeth provided with all hard tissues is the following: A fresh tooth, or one kept a short time in chromic-acid solution, is sliced under water by a watch-spring saw, and ground as thin as possible upon a corundum-wheel of a lathe, always being kept under water. The lamella thus obtained should be placed in a large quantity of chromic-acid solution of the strength of half of one per cent. for one or two days, with the view of hardening the soft parts of the tooth and dissolving the lime-salts. After this the specimen may be stained with carmin, hæmatoxylin, chloride of gold, etc., as above described, and mounted in glycerin.

The saturated solution of picric acid in water may also be used for the decalcification of a ground slice of a tooth, though the precipitated acid must be afterward removed, either by a brush or the blade of a knife. Very handsome specimens can be obtained by staining them with carmin after the treatment with picric acid.

Examination.—We know that the basis-substance or matrix of the dentine is analogous to that of bone,—*i.e.*, that it is glue-yielding, and at the same time infiltrated with lime-salts. We learned from the researches of E. Neumann that the basis-substance is denser at the walls of the canaliculi, and more resistant to the action of strong acids, which cause the appearance of a sheath around each canaliculus after the solution of the intermediate substance of the matrix between the tubuli. Analogous relations also exist in bone-tissue, in which the basis-substance is decidedly denser on the walls of the lacunæ and Haversian canals.

With low powers we cannot see in the dentine anything more minute than the dentinal canaliculi. These run in curved sigmoidal lines from the boundary of the pulp-cavity to the periphery of the dentine; they are directed obliquely upward in the crown, and assume a more horizontal direction in the region of the neck, while in the root they remain horizontal or sometimes turn downward to a varying extent. Besides the main sigmoidal curvature, each individual canaliculus exhibits a more or less wavy course in its way through the dentine, and the individual curvatures are, as a rule, very marked on the outer periphery of the dentine.

The dentinal canaliculi reach the outer surface of the dentine only on the circumference covered by enamel. On the periphery coated by cementum, including also the neck, the canaliculi terminate before reaching the cementum, and are replaced by a finely-granular basis-substance greatly varying in width.

The distribution of the dentinal canaliculi is in the great majority of teeth uniform throughout the dentine, although exceptionally the writer has met with specimens of dentine in which there were smaller or larger territories devoid of dentinal canaliculi; which latter looked as if arranged in bundles or groups within the basis-substance. This relation is especially visible on transverse sections of the dentine. An irregular arrangement of the dentinal canaliculi is more common in the roots than in the crowns.

Each canaliculus contains a dentinal fiber. These fibers, when viewed with a power of 500 on good chromic-acid specimens, exhibit a pale-gray color, and run without ramification through the middle of the canaliculi up to the outer surface of the dentine. The outlines of these fibers always look beaded and fringed. On specimens treated with chloride of gold, the fibers and their delicate offshoots show a distinct violet color, characteristic of living matter within protoplasmic formations, while the space between the fiber and the wall of the canaliculus remains unstained, and the basis-substance between the tubuli only assumes a slight violet tinge.

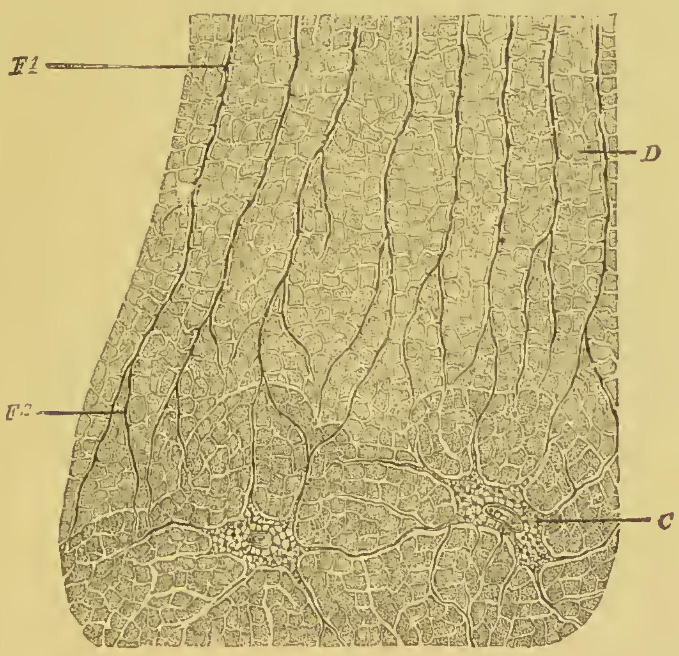
Longitudinal sections of dentine, stained with carmin or chloride of gold, if examined with high powers,—from 1000 to 1500 diameters (immersion lenses),—exhibit the following:

The canaliculi of the dentine run in a more or less wavy course through the basis-substance, and are, as a rule, bifurcated only at the periphery of the dentine, both toward enamel and cementum. Each canaliculus contains a central, slightly beaded fiber, which on its whole periphery sends delicate thorn-like elongations through the light space between the central fiber and the wall of the canaliculus. The thorns are distinctly conical, their bases being attached to the dentinal fibers, and their points directed toward the basis-substance. The smallest thorns spring in an almost vertical direction from the dentinal fiber, while somewhat larger offshoots may run obliquely through the basis-substance, and directly unite neighboring fibers with one another in the vicinity of the enamel and cementum.

The basis-substance shows a distinct net-like structure. The light spaces surrounding the dentinal fibers send delicate elongations into the basis-substance, in which, through repeated branching, a light net-work is established, the meshes of which contain the decalcified glue-yielding basis-substance. The finest offshoots of the dentinal fibers can be traced only into the mouths of the elongations of the canaliculi; on the periphery of the latter, owing to their great delicacy, the offshoots are lost to sight. Coarser offshoots of the dentinal fibers, at the localities mentioned before, traverse the basis-substance within its light net-work, at the same time uniting dentinal fibers directly, and sending slender conical offshoots into the light net-work of the basis-substance. (See Fig. 42.)

The dentinal fibers are either in direct connection with coarser offshoots of the protoplasmic bodies of the cementum, or the light net-work of the basis-substance of the dentine is in communication with that of the basis-substance of the cementum.

FIG. 42.



ROOT OF MOLAR STAINED WITH CHLORIDE OF GOLD.

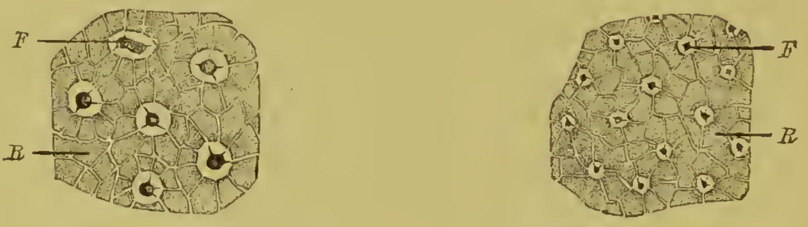
D, dentine; *C*, cement with branching bone-corpuscles; F^1, dentinal fibers with their transverse offshoots; F^2, ramifications of dentinal fibers and their union with the offshoots of cement-corpuscles. Magnified 1200 diameters.

The latter condition prevails at the periphery of the neck of the tooth, where the basis-substance of the dentine is pierced not by larger offshoots of the dentinal fibers, but only by a delicate net-work, through which the connection between dentine and cementum is indirectly established.

Where the dentine is in contact with the pulp, the dentinal fibers communicate directly with the odontoblasts (John Tomes) in a growing tooth, and with the protoplasmic bodies of the pulp in a fully-developed condition, where no regular odontoblasts can be seen.

In cross-sections of dentine the dentinal canaliculi are visible in the shape of circular or oblong holes; the center of each is occupied by the dentinal fiber, which has the shape of a small roundish dot. Again we see that the periphery of the dentinal canaliculus is sharply marked, and repeatedly interrupted by light offshoots leading into the light net-work that pierces the basis-substance between the canaliculi. The central fibers look very distinct and dark violet in specimens stained with chloride of gold, and send slender, conical, radiated offshoots through the surrounding dentinal canaliculi, respectively toward the mouth of the light interruptions in their walls.

Fig. 43.



Cross-Section of Dentine of Incisor. Stained with Chloride of Gold. Main Mass of Dentine.

Cross-Section of Dentine of Incisor. Stained with Chloride of Gold. View from Outer Periphery of Dentine, near Enamel.

F, dentinal canaliculi with the central dentinal fibers, the latter with star-like offshoots; *R*, the basis-substance between the canaliculi, pierced by a delicate light net-work. Magnified 2000 diameters.

In directly transverse sections, one, two, or sometimes even three such offshoots can be seen in a star-like arrangement. Each offshoot springs with a broad base from the central dentinal fiber, while its pointed end always is directed toward the perforation in the wall of the canaliculus, where, as a rule, it is lost to sight. Slightly oblique sections of the canaliculi exhibit both transverse and longitudinal projections of the dentinal fibers. In such an oblique section we may succeed, by cautiously changing the focus, in seeing star-like radiated offshoots up to five in number, all arising from a single dentinal fiber.

Toward the boundary between dentine and enamel, and dentine and cementum, as is well known, the dentinal canaliculi ramify, and according to their ramifications also the dentinal fibers bifurcate, becoming the thinner the nearer they are to the surface of the dentine. Both longitudinal and transverse sections of this part of the dentine show details identical with the main mass of the dentine, the only difference being that near the periphery of the dentine the fibers are more delicate and more closely arranged. (See Fig. 43.)

In some teeth I have met on the periphery of the dentine of the crown with the so-called "interglobular spaces" (Czermak), which may be considered as remnants of the embryonic condition of the dentine. They represent lacunæ of greatly varying sizes, bounded by curved lines, the convexities of which are directed toward the central cavity. These spaces sometimes contain protoplasm,—that is to say, embryonal elements which have not been transformed into basis-substance and not calcified. The dentinal fibers enter the protoplasmic bodies, and each fiber is united with the net-work of the protoplasm by means of delicate thorn-like projections. At other times the basis-substance of the dentine is developed within the interglobular spaces, but devoid of lime-salts. In this instance the dentinal fibers, without investment and without changing their course, pierce the basis-substance and send offshoots to this through the surrounding light spaces.

The dentine shows, in general, though not constantly, peculiar formations where it approaches the enamel and cementum. These formations, however, being in close relation to the covering tissues of the tooth, I prefer to describe in the chapter on cementum and enamel.

Results.—The dentinal canaliculi are excavations in the basis-substance of the dentine, each containing in its center a *fiber of living matter.* Besides the dentinal canaliculi, there exists an extremely delicate net-work within the basis-substance of the dentine, into which innumerable offshoots of the dentinal fibers pass. Although evidently, by reason of its delicacy, we cannot trace the living matter throughout the whole net-work in the basis-substance, we are justified in assuming that not only are the dentinal canaliculi, but so also is the whole basis-substance of the dentine, pierced by a delicate net-work of living matter. The living matter of the dentine is in direct union with that of the protoplasmic bodies of the pulp, of the cementum, and of the enamel.

Further researches into the minute structure of dentine have been made by John I. Hart,* of which the following is an abstract:

"**Method.**—A freshly extracted tooth, preferably a deciduous one, is sawed into sections, either vertical or transverse, with the precaution that the tooth, and the instrument employed, are kept constantly moist with a one or two per cent. solution of sodium chloride. The object of this procedure is to prevent the drying up and consequent shrinkage of all soft constituents of the dentine,—viz, the dentinal fibers and their offshoots. The slab thus obtained is ground first with a coarse corundum-wheel on the lathe, and afterward on a corundum-slab of medium grit, always under a weak solution of table-salt. I wish to lay stress upon the fact that the ground slabs should not be kept longer than two hours in the salt solution, lest the dentinal fibers should become hydropic, and, swelling up, completely fill the canaliculi. Before staining, with a camel's-hair brush cleanse the specimen of the adhering *débris* resulting from the grinding. The next process is staining with a one-half of one per cent. solution of chloride of gold, or a one per cent. solution of hyperosmic acid. Since the latter has proved inferior to the former, it has been abandoned, and chloride of gold is exclusively employed. Two ways have been adopted. Pour the chloride-of-gold solution over the slab and leave it immersed two hours, carefully shutting off the light; then transfer the slab with a wooden spatula, carefully avoiding all metallic instruments, into a six per cent. solution of glacial acetic acid for two hours. Repeat this procedure,—viz, staining with the gold salt and decalcifying with acetic acid from ten to twelve hours, after which the now pliable slab is left exposed to strong daylight in distilled water until it has assumed a dark-violet color; or expose the slab to the action of the gold salts for ten hours, and then to the solution of acetic acid for the same length of time, and expose to light in distilled water. The latter method is preferable, although the specimens are sometimes partially overstained and become too dark for examination. After the required color is reached, brush the specimen gently in order to remove the precipitations of the gold salt, and mount in chemically-pure glycerin.

"There is a marked difference in the behavior of enamel and that of dentine in the process of decalcification by acetic acid.

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* "Minute Structure of Dentine." *Dental Cosmos*, 1891.

Enamel at first breaks up into prisms with transverse blocklets, similar to those obtained by treatment with dilute hydrochloric acid. Upon the approach of complete decalcification, the enamel becomes extremely brittle, and breaks up into small pieces if the least pressure is exerted upon it. After complete removal of the lime-salts, there is left, as first seen and described by Dr. Frank Abbott as early as 1878, only a delicate reticulum, —the last residue of organic material.

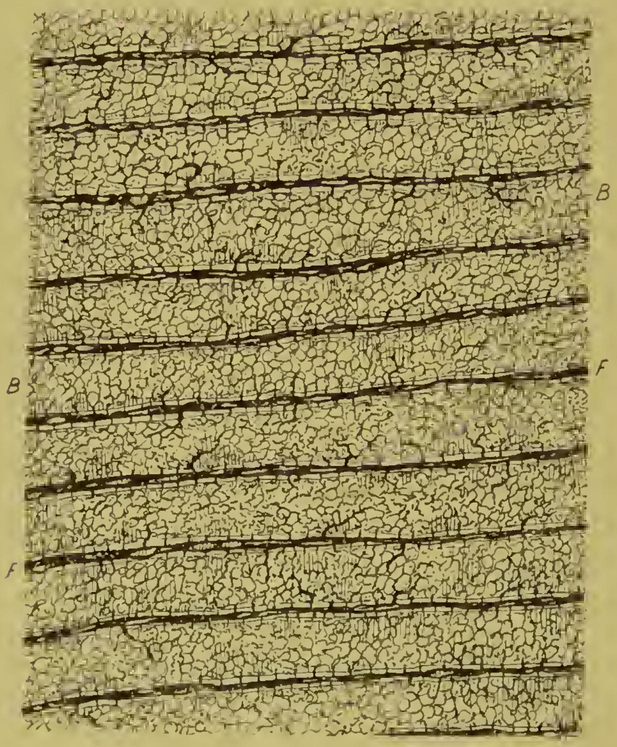
"Dentine resembles enamel only in this particular, that in incomplete decalcification, blocklets of lime-salts are seen throughout the basis-substance. After complete decalcification a tough, pliable slab is left, which, even though exposed to some pressure, will not break asunder. Obviously the glue-yielding basis-substance and its tenants are not corroded or affected in the least by the six per cent. solution of acetic acid. All this acid accomplishes is the removal of the lime-salts deposited in the basis-substance, thereby rendering clear its minutest structure. Exposure of a ground slab of dentine to the action of the gold solution for three hours renders the dentinal fibers plainly visible and tinted a pale violet. Exposure of six hours will stain the dentinal fibers dark violet, and will bring out clearly the broader offshoots. An exposure of from nine to ten hours is necessary to bring forth the more minute conical offshoots emanating from the dentinal fibers and the minutest structure in the basis-substance.

"**Main Mass of Dentine.**—If successfully stained portions are placed under an amplifying power of from 1000 to 1200 diameters, striking features become recognizable in the dentinal fibers themselves. Should the method described above be faithfully carried out, we will invariably see portions of a varying extent suitable for the amplification just stated. It makes no difference whether water or cedar-oil immersion is resorted to.

"The dentinal fibers in the main mass of the dentine do not look homogeneous, as in the unstained condition, but appear hollowed out in their interior by light spaces, so-called vacuoles, of greatly varying sizes. These vacuoles are plainly visible if the ground slab is left exposed for the shortest possible time to the salt water. If this exposure is protracted for days, the vacuoles will appear enlarged and almost continuous within the dentinal fibers. Both longitudinal and transverse sections exhibit the vacuoles: I have obtained the most distinct image, however, in thin longitudinal sections, where but one layer of dentinal fibers was visible. (See Fig. 44.)

"From the rather uneven periphery of the dentinal fibers arise a smaller number of broad and a large number of delicate conical offshoots, all of a dark-violet tint. These offshoots pierce in an almost rectangular direction the light space of the dentinal canaliculus, and inosculate with a minute dark-blue net-work pervading the whole basis-substance of the dentine. This net-work being present throughout the basis-substance, serves for a direct interconnection of all dentinal fibers. The net-work appears uninterrupted wherever sufficiently stained, although we may fail to trace the connections in some limited portions of the basis-substance. In transverse sections of the dentinal canaliculi, such as we invariably obtain in longitudinal sections of the crown, and, as a matter of course, in transverse sections of any part of the tooth, we notice features identical with those of longitudinal sections. (See Fig. 45.)

Fig. 44.

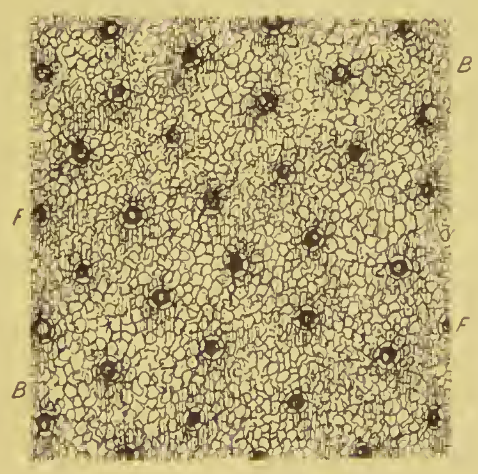


Main Mass of Dentine of a Temporary Tooth, Stained with Chloride of Gold, Decalcified with Acetic Acid.

F, F, dentinal fibers, partly vacuoled; *B, B,* basis-substance, traversed by a reticulum. Magnified 1200 diameters.

"The dentinal fibers of somewhat varying diameters exhibit hollow centers in many instances. From their periphery, broad and narrow offshoots spring forth in a considerably larger number than ever visible in sections of teeth not treated with chloride of gold. The basis-substance appears to be traversed by a dark-violet reticulum of the same character as that of longitudinal sections. Oblique sections will of necessity show an apparently larger number of dentinal canaliculi and their tenants than longitudinal or transverse sections in a given area of dentine. Here we often obtain the impression that rectangular offshoots of one dentinal fiber inosculate directly with neighboring fibers, thus furnishing a pretty figure of a ladder with minute rungs.

Fig. 45.



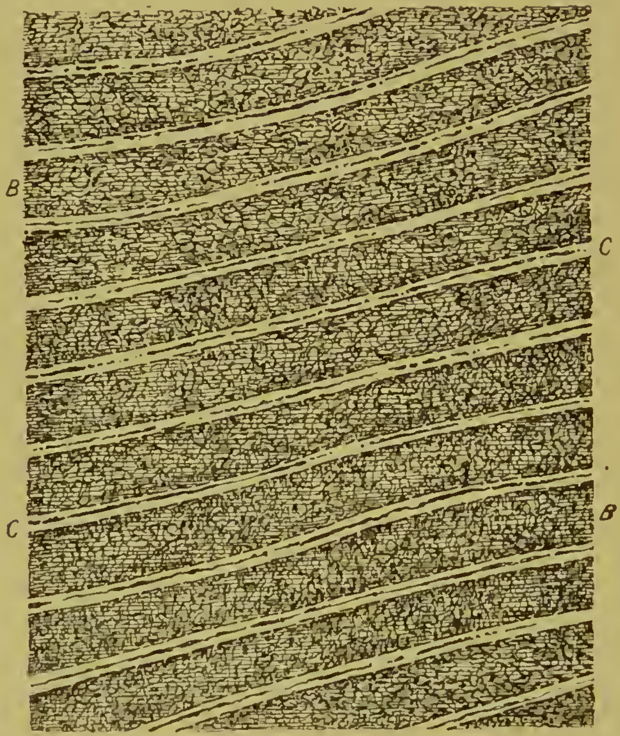
Dentine of Temporary Tooth. Transverse Section of Canaliculi, Stained with Chloride of Gold, Decalcified with Acetic Acid.

F, F, dentinal fibers, with radiating offshoots piercing the space of the canaliculi; *B, B*, basis-substance traversed by a delicate reticulum, in connection with the dentinal fiber. Magnified 1200 diameters.

"All that I have described thus far as being present in the main mass of the dentine is plainly visible only in the dentine of teeth that were alive at the time of extraction. If life has been destroyed to a varying extent by an alveolar abscess or pyorrhea alveolaris, the image furnished by the dentine is so characteristic that we recognize at the first glance the extinction of life. Several times have I ground teeth without knowing that they were dead. The microscope revealed the fact. (See Fig. 46.)

"In longitudinal sections, only the canaliculi are conspicuously prominent, exhibiting delicate and numerous interruptions along their walls. The dentinal fibers appear shriveled up to rows of minute granules, not always in the center of the canaliculus, but frequently quite near to one of the walls. The granules often appear interrupted to a considerable extent, and sometimes the remnants of the dentinal fibers are missing altogether. No conical offshoots emanate from the remnants of the dentinal fibers. The basis-substance shows a rather faint and indistinct reticulum, lacking connections in numerous places. In transverse sections of dead portions of the dentine we obtain a striking image. (See Fig. 47.)

FIG. 46.

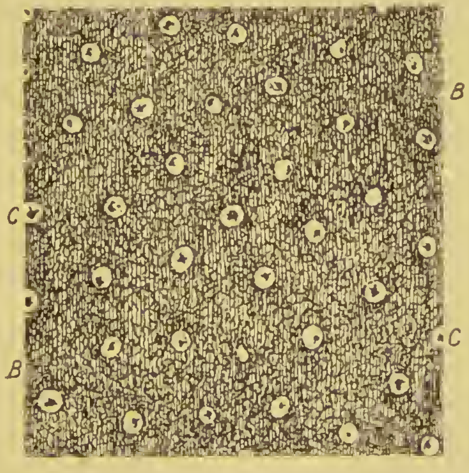


DENTINE OF A DEAD TEMPORARY TOOTH, STAINED WITH CHLORIDE OF GOLD, DECALCIFIED WITH ACETIC ACID.

C, C, canaliculi, holding shriveled dentinal fibers; *B, B,* basis-substance, holding a shriveled reticulum. Magnified 1200 diameters.

"We see the dentine pierced by light spaces at almost uniform distances, many of which contain dark-violet granules or vestiges of a previous dentinal fiber. There are but scanty and incomplete indications of conical offshoots emanating from the shrunken dentinal fibers. The basis-substance is of the same character as found in longitudinal sections. The basis-substance shows a rather indistinct dark-violet reticulum with numerous interruptions. The facts here described suffice, in my judgment, to determine the nature of the reticulum pervading the whole of the dentine; it is of necessity the living matter which is plainly marked in living, and shriveled and reduced to a row of granules in dead teeth. Since we know of no tissue constituted of nerves, we cannot support the suggestion of John Tomes, that dentinal fibers are but nerve-fibers carrying sensation from the periphery to the center. Since we know that non-medullated nerve-fibers have the same structure as the dentinal fibers, we must conclude that both the nerves and dentinal fibers are made up of living or contractile matter, the contraction of which is facilitated by the presence of vacuoles. For, according to modern researches, the conduction of sensation centripetally and of motion centrifugally is very probably instituted by the contraction of living matter.

Fig. 47.

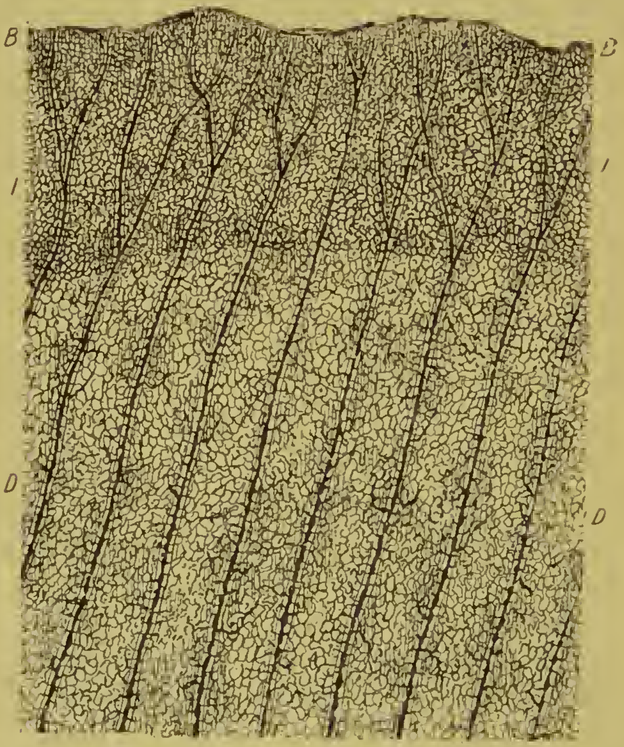


Dentine of a Dead Temporary Tooth. Transverse Section of Canaliculi, Stained with Chloride of Gold, Decalcified with Acetic Acid.

C, *C*, dentinal canaliculi, holding shriveled dentinal fibers; *B*, *B*, basis-substance, containing a shriveled, indistinct reticulum. Magnified 1200 diameters.

"**Interzonal Layer between Dentine and Enamel.**—In all the provisional teeth that I have examined, a zone of varying breadth was visible along the outer periphery of the dentine, conspicuous by a darker violet stain than the rest of the dentine. In fact, this region is rather prone to be overstained and become too dark for examination with high powers; hence, we should examine this region before it has assumed a deep stain, owing to a protracted exposure to light. The first feature which strikes us upon approaching the outer periphery of the dentine is the beaded appearance of the dentinal fibers, lacking vacuoles in this situation. The fibers are bifurcating, as is well known, and, becoming more and more delicate, correspondingly exhibit more and more beads. The reticulum into which the lateral conical offshoots of the dentinal fibers inosculate is extremely dense,—much more so than in the rest of the dentine. The densely reticulated zone usually corresponds to the depth of the bifurcations of the dentinal fibers; in other words, it commences in a rather abrupt line in the height in which bifurcations begin to appear. (See Fig. 48.)

FIG. 48.



DENTINE OF TEMPORARY TOOTH, NEAR ENAMEL, STAINED WITH CHLORIDE OF GOLD, DECALCIFIED WITH ACETIC ACID.

B, B, boundary of dentine toward enamel; *I, I*, interzonal layer (Atkinson), with a dense reticulum, dentinal fibers bifurcating; *D, D*, main mass of dentine, holding beaded dentinal fibers. Magnified 1200 diameters.

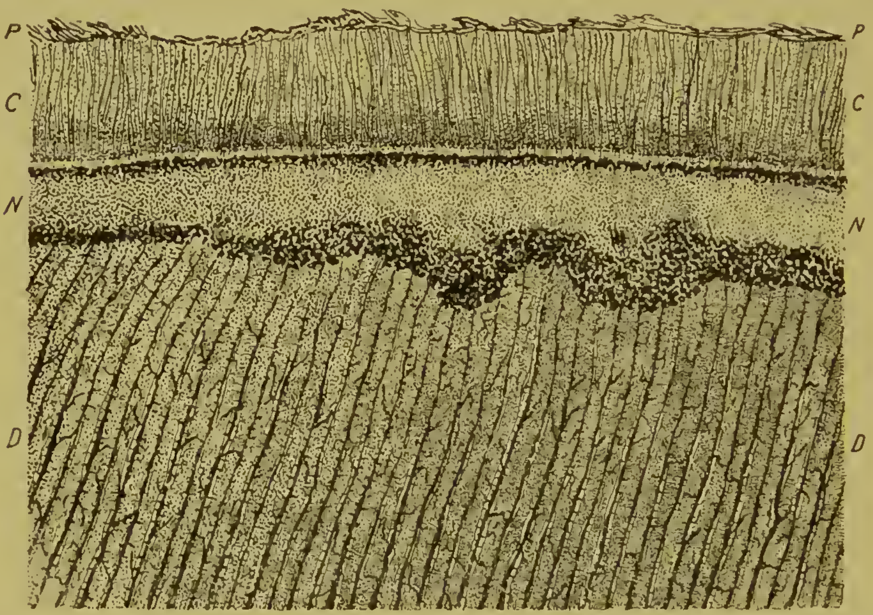
"The presence of this dense reticulum of living matter evidently explains the fact that the interzonal layer between enamel and dentine is so extremely sensitive. I am sure that every dentist is made aware of this striking fact when cutting into dentine. The dentinal fibers rarely enter the enamel in human teeth, but the reticulum of the dentine is continuous with that of the enamel. This connection, however, I was unable to trace myself, as in all my specimens the enamel was dissolved and removed by the camel's-hair brush prior to mounting.

"**Interzonal Layer between Dentine and Cementum at the Neck of the Tooth.**—Ever since John Tomes drew attention to the peculiar fact that the dentinal fibers stopped short of the cementum, special attention has been paid to this region of the dentine, since it is also known to be more sensitive than the rest of the dentine. According to Tomes, 'the greater degree of sensitiveness observable in the dentine immediately below the enamel,—that is, at the point of ultimate distribution of the dentinal "tubes," and consequently of their contents,—may be fully accounted for on the supposition that the latter are organs of sensation, the highest sensibility of which is confined to their branches.'

"This hypothesis does not find foundation in the region of the neck, where bifurcations of dentinal fibers are often missing or are scanty. There is only a uniformly granular layer visible in unstained and ground specimens between the surface of the dentine and the terminal points of the dentinal fibers. Still, the sensitiveness at the neck is undoubtedly even greater than that of the interzonal layer of the crown. Bödecker drew attention to the fact that in the great majority of teeth the finest terminations of the dentinal fibers are lost to sight in a net-work somewhat coarser than that of the basis-substance of ordinary dentine. Sometimes, he says, the dentinal canaliculi upon approaching the periphery become slightly dilated, so as to produce slender pear-shaped cavities, in accordance with which the terminating dentinal fibers exhibit slight enlargements.

"I can corroborate this statement from what I have seen in my own specimens of temporary teeth. Several times I have met with peculiar formations in this region, which, as far as I am aware, have not as yet been described. (See Fig. 49.) In unstained slabs of temporary teeth I have seen coarsely granular layers in the dentine at the region of the neck, with which the dentinal fibers directly inosculated. After deep staining with chloride of gold, the granular layers became dark violet and easily recognizable with low powers of the microscope. I found, as a rule, one or two granular layers like narrow ribbons running along the outer periphery of the dentine, close to the cementum. A much more irregular and broader granular layer was seen at a certain distance below the surface, producing wavy lines, and being in connection externally with a more uniformly granulated layer, and internally with the dentinal fibers. This peculiar configuration was plainest at the portion of the cementum made up of spindles at the neck of the tooth, and gradually faded downward, where the lamellated layer of the cementum began to make its appearance. High powers of the microscope revealed the intimate structure of this portion. (See Fig. 50.)

FIG. 49.



NECK OF TEMPORARY TOOTH. LONGITUDINAL SECTION, STAINED WITH CHLORIDE OF GOLD, DECALCIFIED WITH ACETIC ACID.

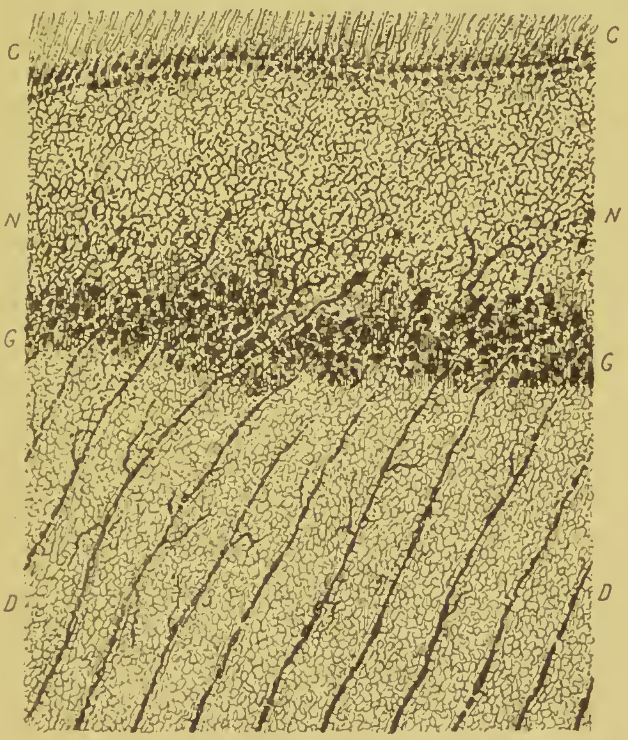
D, *D*, dentine, main mass; *N*, *N*, dentine of neck, bordered upward and downward by coarsely granular layers; *C*, *C*, cementum of neck; *P*, *P*, shreds of pericementum. Magnified 400 diameters.

"The fibers in this situation appear reduced in caliber, and show a beaded structure much the same as at the periphery of the crown. These fibers either terminate in pear-shaped enlargements, or in irregularly-shaped dark-violet lumps, which send delicate offshoots in all directions, serving as an intercommunication between them. The large number of these lumps causes the granular appearance of the dentine. The following broader zone, which with lower powers has appeared uniformly granular, is now dissolved into a rather coarse reticulum—much coarser than that of the interzonal layer of the crown. This reticulum shows stray irregular fibers. Both the latter and the lumps are in close connection with the reticulum.

"At the outermost periphery we again notice one or two rows of enlargements, which, judging from the regularity of their arrangement, correspond to the bases of the spindles, building up the cementum of the neck. This large amount of living matter satisfactorily explains the extreme sensitiveness of the region of the neck.

"**Results.**—To sum up my observations, I must maintain the presence of a reticulum of living matter throughout the dentine.

FIG. 50.



DENTINE OF NECK OF TEMPORARY TOOTH, STAINED WITH CHLORIDE OF GOLD, DECALCIFIED WITH ACETIC ACID.

D, D, dentine; *G, G*, coarse globules, into which the dentinal fibers inosculate; *N, N*, dentine of neck, with a coarse reticulum, lacking fibers; *C, C*, cementum of neck, bordered by a granular layer toward the dentine. Magnified 1200 diameters.

It is decidedly coarser than that seen and described by Frank Abbott in the enamel. It is most delicate in the interzonal layer of the crown between dentine and enamel, and coarsest in the region of the neck bordering on the cementum.

"My assertion finds proof by comparison of living with dead teeth, for in the latter the dentinal fibers were reduced to a series of granules, and the basis-substance appears irregularly dotted or spotted, instead of being reticular. The microscope therefore easily reveals the difference between living and dead teeth. Another point of confirmation is that the portions of the dentine being most sensitive are richest in the supply of living matter, not in that of the fibers which are missing in the interzonal layer of the dentine of the neck, but in that of the basis-substance."

Further researches into the presence of the reticulum in dentine have been published by Carl Heitzmann,* as follows:

"Dr. Bödecker had collected a large number of teeth that were filled for months and years. The first tooth he ground thin was a bicuspid with two cavities in its crown; one filled with cement, the other with silver amalgam,—both plugs having been in the cavities for years. How great was his surprise when, examining the border of the cavity previously filled with amalgam, he saw a dark-brown discoloration of the dentine, not directly along the border of the cavity, but some distance away from it, and in this brown zone the dentinal canaliculi, respectively their tenants, the dentinal fibers, crowded with black dots, and their offshoots rendered wonderfully plain by a black deposit. In the darkest portion the reticulum was easily seen with comparatively low powers of the microscope,—viz, 500 diameters. (See Fig. 51.)

"The border of the cavity is, in the upper portion, seen in the breadth of the specimen, and here it holds a number of black metallic particles, evidently not of the amalgam itself, but of a sulphur-combination of the silver or quicksilver. The zone of the dentine directly bordering the cavity is, apparently, destitute of structure, showing but faint traces of canaliculi; of a high refraction, obviously in a state of consolidation, a reactive process subsequent to the filling. Close beneath this consolidated layer follows a dark-brown zone, diffusively pigmented, and here we see the dentinal canaliculi crowded with black metallic particles, considerably widened and sending black offshoots into the basis-substance between the canaliculi. The offshoots are comparatively scarce and large toward the enamel, where the unstained canaliculi show only the usual bifurcation. The offshoots are more numerous upon entering the dark-brown region of the dentine, and in the darkest portion are so numerous and so delicate that the power of five hundred diameters is insufficient to dissolve the minutest branches, all of which inosculate into an extremely delicate black reticulum. All the features, the coarse and fine offshoots and their union into a reticulum, are identical with the image obtained by John I. Hart in living dentine, treated with chloride of gold.

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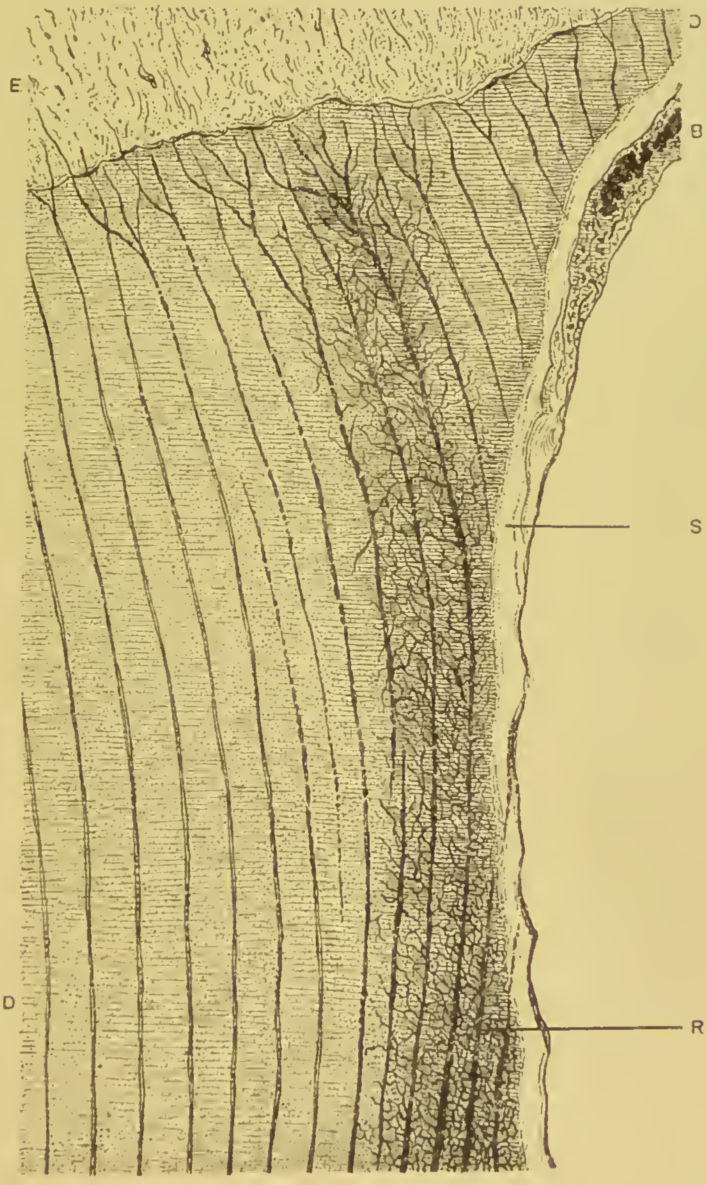
* "Demonstration of the Reticulum in Dentine with Low Powers of the Microscope." Transactions of the New York Odontological Society, 1892.

Fig. 51.



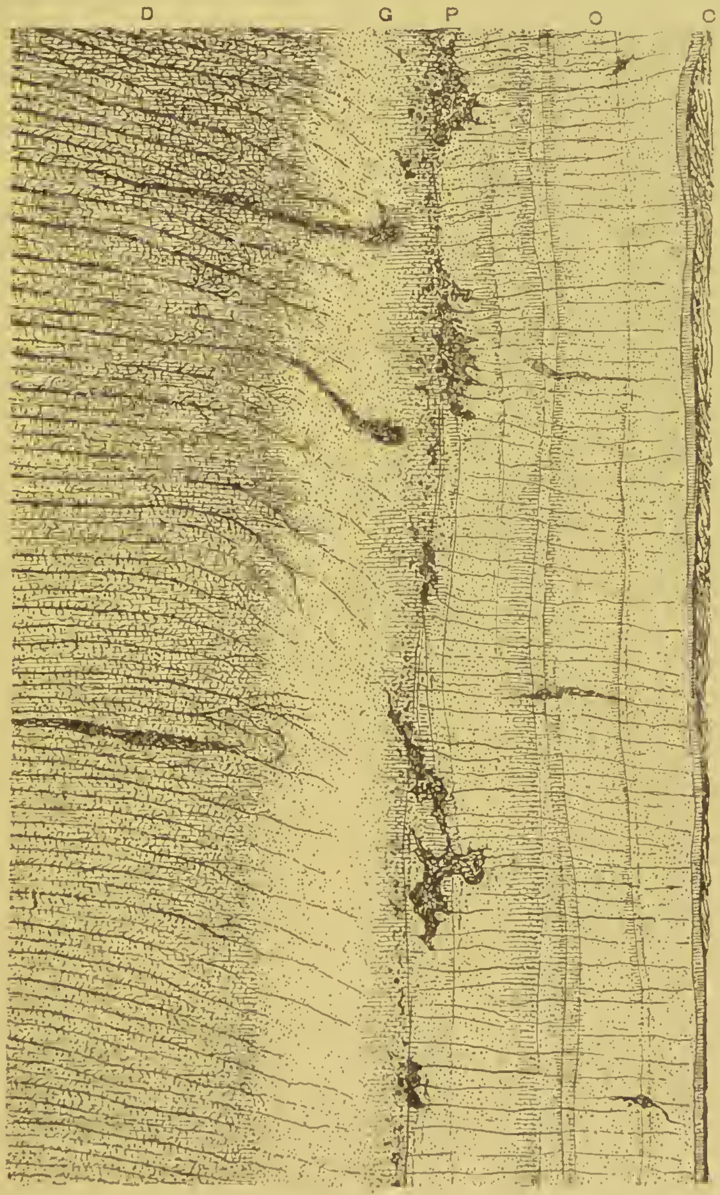
Ground Bicuspid. Cavity of the Crown previously filled with Amalgam.

E, enamel; *D*, *D*, dentine; *B*, border of cavity; *S*, solidified dentine along the border of the cavity; *R*, reticulum, brought forth by the amalgam. Magnified 500 diameters.

"How did the metallic particles reach the dentinal canaliculi, and produce such an image at a certain distance away from the border of the cavity? There is but one answer possible to this query. The metallic particles were taken into the living matter, probably before the consolidation was accomplished at the border of the cavity, and carried farther, at the same time rendering visible the reticulum, interconnecting the dentinal fibers. It would be impossible to understand the loading of the dentinal fibers, which run a parallel course and are separated from one another by the intervening basis-substance, unless by the presence of transverse connections of the fibers, as actually shown by the reticulum. This reticulum is, in fact, so plain that any tyro must see it, and the specimen alone is sufficient to remove the doubts of even the most skeptical minds.

"Fig. 52 represents the neck of a molar whose pulp years ago was treated by Wilhelm Herbst, of Bremen, Germany, with his method, made known in this country by Dr. Bödecker. Dr. Herbst applies cobalt upon the exposed or inflamed pulp of the crown; a few days afterward he excises the pulp down to the root-canals; introduces tin foil, which he grinds down at the bottom of the cavity, thus shutting off the pulp of the root-canals from contact with air, or other filling-materials placed into the cavity of the crown. The remarkable outcome of Bödecker's examination of the teeth sent by Herbst is that the pulp remains alive in the root-canal, and is sufficient to endow with life the whole tooth, though its crown is entirely deprived of its pulp. This fact becomes intelligible only upon the presence of interconnections between the parallel dentinal fibrillæ; for the dentinal fibers could not possibly be kept alive in the crown, unless by unions with the fibrillæ of the roots, the only ones kept directly alive by the pulp-tissue of the roots. This is an indirect, though stringent proof of the presence of the reticulum. The direct proof is furnished by the visible interconnections of the fibrillæ along the neck of the tooth, of a brownish color, in a slightly brownish basis-substance. After having examined many hundreds of teeth under the microscope in all sorts of pathological changes, I have never met with such a discoloration in the dentine so frequently observed in the enamel. It is quite possible and reasonable to assume that the metallic salt, originated at the border of the cavity, was transferred into the dentinal fibers and their offshoots, and was, at last, deposited in the fibrillæ and their offshoots in the region of the neck, which, as John I. Hart's researches prove, abounds in living matter far in excess of any other portion of the dentine. This, I admit, is a hypothesis, to which I resort for lack of a better

Fig. 52.



Ground Molar. The Pulp previously treated by the Herbst Method. The Cavity filled with Amalgam.

C, pericementum; *O*, osteoid layer of cementum; *P*, protoplasmic bodies at the interzonal layer between cementum and dentine; *G*, granular layer of dentine of the neck; *D*, dentine of neck. A few club-shaped enlargements of dentinal canaliculi. The reticulum brought forth by the amalgam. Magnified 500 diameters.

explanation; it is nearest to my mind, after thirty-two years of study of the teeth, having become so thoroughly convinced of the life of all constituent tissues of the teeth. The specimen under consideration exhibits an ill-calcified dentine, for it shows numerous protoplasmic bodies at the border of the dentine toward the osteoid layer of the cementum, and club-shaped enlargements of some dentinal fibrillæ. The granular layer of Tomes in the dentine of the neck destitute of dentinal canaliculi is narrower than in thoroughly calcified teeth; but present, nevertheless."

CHAPTER XI.

THE MINUTE STRUCTURE OF ENAMEL.*

The best specimens for examination of enamel I obtained by grinding fresh teeth, and staining them for one hour with a half per cent. solution of chloride of gold.

Up to this time the impression of most examiners has been that the enamel is built up of bundles of rods, or prisms, crossing one another, and traversed by faint vertical lines, which give each of them the appearance of a column, subdivided into small squares. The enamel-rods doubtless exist, and are wavy near the dentine, and straight on the periphery and the main mass of the enamel. They may be considered as columns of a calcified substance, between which minute spaces are left, analogous to the cement-substance of epithelial formations.

In longitudinal sections we see delicate beaded fibers, which occupy the central portion of the interstices between the enamel-rods. These fibers I propose hereafter to term the "enamel-fibers." (See Fig. 53.)

From such a fiber arise very minute conical fibrillæ, which traverse the tiny intervals between the fiber and the neighboring outlines of the rods, and fade away where they enter the latter. The columns of the basis-substance themselves are pierced by delicate canaliculi, running in an almost vertical direction to the enamel-rods, regularly enough to give the appearance of squares, although these are much smaller than usually represented in the books. In the midst of a minute square, light canals are seen, not infrequently running parallel with the outlines of the enamel-rod. The square fields thus produced by the rectangular crossing of light channels look, under the power of 1200 diameters, finely granular. In specimens not fully decalcified it is impossible to decide whether there is a light net-work within the enamel-prisms analogous to that in the basis-substance of the dentine and cementum, or whether the granular appearance is merely due to the deposition of lime-salts. In thoroughly decalcified specimens of enamel, however, such as were first made by Dr. Frank Abbott, there is no difficulty in seeing, with high powers, the reticular structure of protoplasm.

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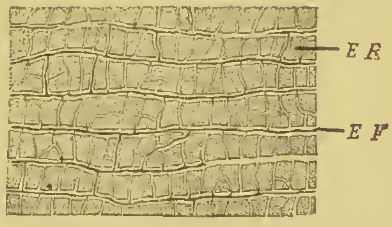
* "The Distribution of Living Matter in Human Dentine, Cement, and Enamel." *Dental Cosmos*, 1878–1879.

Cross-sections of the enamel, which we obtain also in longitudinal sections of the tooth, on account of the different directions of the bundles of the enamel-rods, plainly exhibit the irregular polyhedral fields of the intersected enamel-rods. The light interstices between the polyhedral fields contain in many instances delicate beaded fibers, surrounding the polyhedral fields of the enamel-rods. The fibers, if cut transversely, have the appearance of dots. They connect with one another directly or by means of intervening delicate threads.

FIG. 53.



LONGITUDINAL SECTION OF ENAMEL.

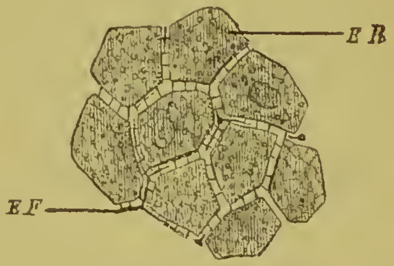
ER, enamel-rods, traversed by prevailing vertical spaces; *EF*, enamel-fibers, branching and partly uniting by delicate offshoots. Magnified 1200 diameters.

Extremely fine thorns traverse in a vertical direction the light space between two neighboring enamel-rods, even where a fiber is not visible (see Fig. 54).

The rods of the enamel are, on an average, half the diameter of the columns of the basis-substance in dentine; therefore four columns of the former will correspond to two of the latter, and consequently two dentinal fibers will answer to four enamel-fibers. Sometimes in the cross-section of an enamel-rod I have met with roundish formations occupying the center of the rod, one or two in number, which, owing to a denser granulation and a surrounding shell, had the appearance of nuclei. The enamel-fibers run a very straight course toward the surface, and are, on the average, a trifle thicker here than near the boundary of the dentine.

The outermost surface of the enamel is covered by flat epithelia (Nasmyth's membrane), which in the transverse section have the appearance of shallow spindles; not infrequently there occurs also a stratified epithelium on the surface of the tooth. The enamel-fibers are in connection with these epithelial bodies, which, if detached, show delicate offshoots adhering in regular intervals—the broken enamel-fibers. Sometimes the surface of the enamel is coated by a thin uniform layer of protoplasm, with regularly scattered nuclei. In such an instance single epithelia are not traceable, though scarcely any doubt can arise about the epithelial nature of this layer.

FIG. 54.



CROSS-SECTION OF ENAMEL.

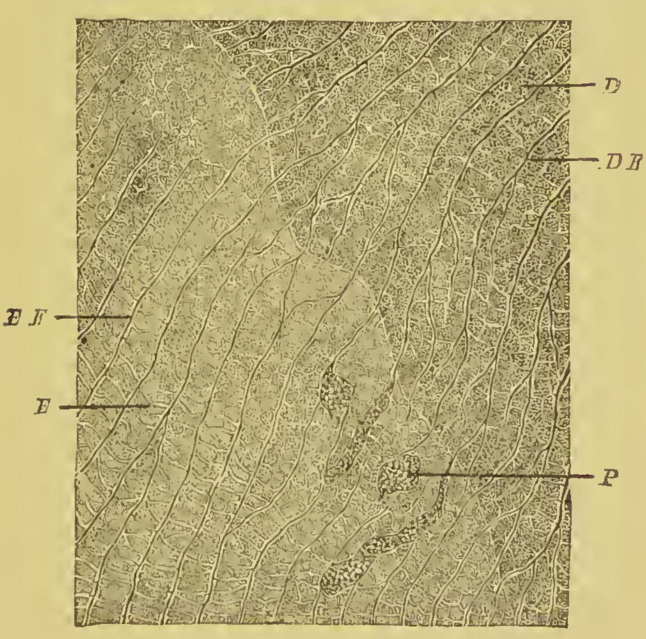
ER, rods of enamel, partly exhibiting formations like nuclei; the light interstices between the rods traversed by delicate beaded fibers, *EF*, or by vertical thorns. Magnified 2000 diameters.

At the place of junction of the enamel with the dentine a direct connection is not infrequently seen between the enamel- and dentine-fibers. The latter, through repeated bifurcations, being closely brought together, continue their course into the enamel-fibers without any interruption. The direction of the fibers of the two tissues, however, is almost never identical, inasmuch as the enamel-rods, and consequently the enamel-fibers, as a rule, owing to their wavy course in this situation, are obliquely intercepted upon the dentine.

We can often trace dentinal fibers up into the enamel for a varying distance, without finding a distinct union between the enamel- and dentine-fibers, as the former do not reach the surface of the dentine, but terminate above its level in different heights, while the zone close above this is occupied by a delicate, irregular net-work, analogous to that of the dentine. Here no rods of enamel are visible either in longitudinal or transverse sections, but with low powers of the microscope only a finely-granular layer is presented.

In many places the dentinal canaliculi, upon entering the enamel, suddenly become enlarged, and form more or less distinctly spindle-shaped cavities of greatly varying diameters, analogous to the spindle-shaped enlargements on the boundary of the cementum. (See Fig. 55.) These enlargements either run in the main direction of the dentinal canaliculi or deviate obliquely. They invariably contain protoplasmic bodies which plainly show the reticular structure, and sometimes contain one or more compact clusters to be considered as nuclei. The spindle-shaped protoplasmic bodies are in direct connection at their proximate ends with the terminations of the dentinal fibers that have arisen from their repeated bifurcations, while on the distal end they may show delicate fibers, viz, enamel-fibers, or delicate conical thorns, traversing the light space between the surface of the protoplasmic body and the wall of the cavity. These thorns are lost to sight on passing into the net-work at

FIG. 55.



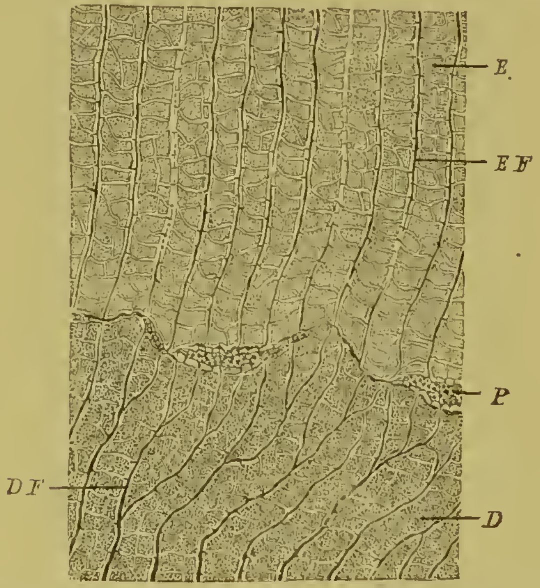
UNION OF DENTINE WITH ENAMEL.

D, dentine; *E*, enamel; *DF*, dentinal fibers, in union with large protoplasmic bodies, *P*, or directly running into enamel-fibers, *EF;* the latter often are lost in the delicate, irregular net-work on the bottom of the enamel. Magnified 1200 diameters.

the bottom of the enamel. In some places, especially on the cusps, the spindle-shaped enlargements of the dentine-fibers are quite numerous, and of an almost uniform size and direction, forming regular rows of spindles within the enamel. In the teeth of younger individuals, the spindle-shaped enlargements are comparatively larger and more regular than in the teeth of old people.

The boundary-line between the dentine and enamel is either straight or slightly wavy, and with more or less deep bay-like excavations, analogous to those on the boundary between dentine and cementum. The concavities of the bays are directed toward the dentine. (See Fig. 56.) In this interzonal layer at the bottom of the bays we meet with fibers occupying the curved spaces between dentine and enamel, or we see in a correspondingly bent course protoplasmic bodies directly connected with the dentinal fibers downward, and with the enamel-fibers upward. In specimens stained with chloride of gold, the dentine is always much deeper in color than the enamel, hence the relations described are plainly marked on such specimens.

Fig. 56.



D, dentine; *E*, enamel; *P*, protoplasmic formations at the boundary between both tissues; *EF*, union with enamel-fibers; *DF*, with dentine-fibers. Magnified 1200 diameters.

Results.—The enamel is traversed by fibers of living matter located in the interstices between the enamel-rods. The fibers are connected with one another by delicate fibrillæ, piercing the enamel-rods in a vertical direction. Besides these rectangular unions, the basis-substance is traversed by a minute net-work of living matter. The enamel-fibers send conical thorns toward the enamel-rods, and such thorns are visible in all interstices between the enamel-rods. The enamel-fibers are continuous on the outer surface with the covering layer of flat epithelia, and on the inner surface with the dentinal fibers. The latter connection is either direct or indirect through a net-work of living matter, or through intervening protoplasmic bodies in the interzonal layer.

Further researches in this field have been made by Frank Abbott.* Of their results the following is an abstract:

"As to enamel, I have never seen the minute relations marked so plainly in permanent as I find them in temporary teeth. Here the enamel-rods are narrower, and the interstices between them wider, than in permanent or adult teeth. A power of 500 diameters of the microscope is sufficient to show plainly in the temporary teeth relations rendered visible in permanent teeth, only by very much higher powers.

"The cut, Fig. 57, is made from a drawing taken with a power of 1200 diameters (immersion). In the enamel the enamel-rods, the fibers in the interstices between the rods, the lateral offshoots of the fibers, and the light reticulum within the rods are represented. As a striking feature, I wish to emphasize the direct connection of the fibers of the dentine with those of the enamel. Thus the width of an enamel-rod is in full correspondence with the width of the fields of basis-substance of the dentine, after the bifurcation of the dentinal fibers, near the boundary between dentine and enamel. In preparing this specimen, it happened that on several portions of the crown a larger portion of the enamel was ground away than was intended; so much so that only shreds of enamel in connection with the dentine were left. On one of these places delicate beaded fibers (*F*) were seen, isolated at their upper ends, while their lower ends could be traced into interstices between the enamel-rods, and into connection with the ends of the dentinal fibers. No doubt here the mechanical injury done to the enamel has luckily led to a tearing out of a few enamel-fibers, which accident plainly illustrates their presence."

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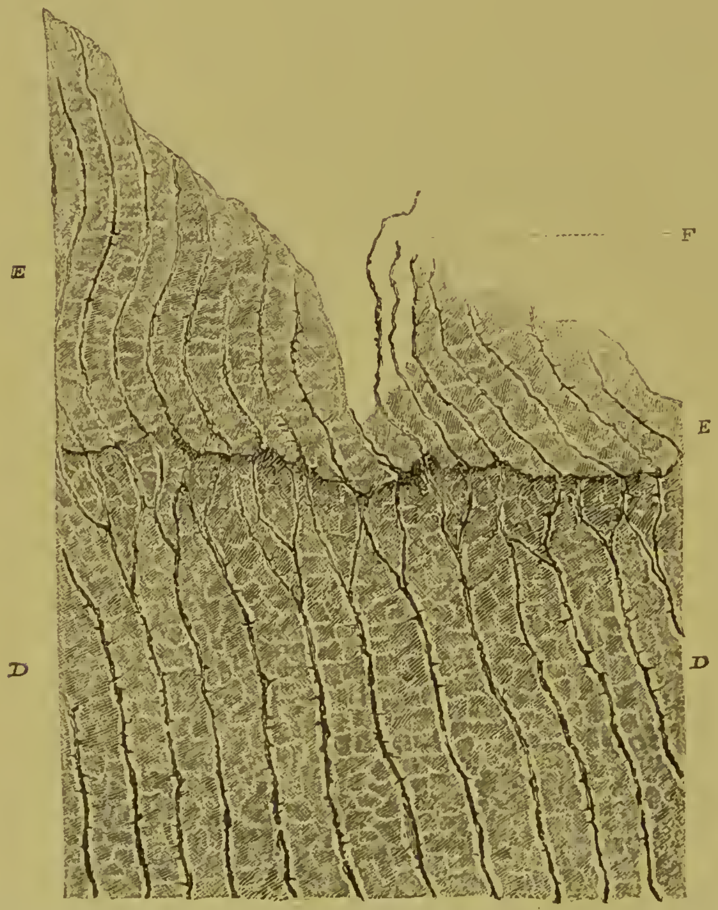
* "The Minute Anatomy of Dentine and Enamel." *Dental Cosmos*, 1880.

The same author, in an article, "A Contribution to the Study of the Minute Anatomy of Enamel,"* says,—

"Dr. George W. Weld, in a paper entitled 'The Destructive Energy of the Tincture of the Chloride of Iron on the Teeth: an Experimental Study,' read before the New York Odontological Society, June 8, 1886, and published in the *Dental Cosmos* for October, 1886, page 627, draws attention to a novel method of treating enamel for the purpose of decalcification.

FIG. 57.



D, D, dentine, with bifurcating fibrillæ toward the enamel; *E, E*, enamel with beaded fibrillæ between the rods; *F*, free fibrillæ of enamel, the rods being torn away. Magnified 1200 diameters.

"Dr. Weld minutely describes how a specimen (thin slab) of enamel previously treated with a six per cent. solution of acetic acid, while watched under the microscope, in consequence of a jarring of the instrument, became broken in pieces, and the enamel-rods isolated, so as to resemble a 'bunch of sticks.' He asserts that 'this method will perhaps ultimately be the means of throwing some light on the matter of the distribution of lime-salts and living matter in the enamel,' but he does not, so far as is known, follow up the study.

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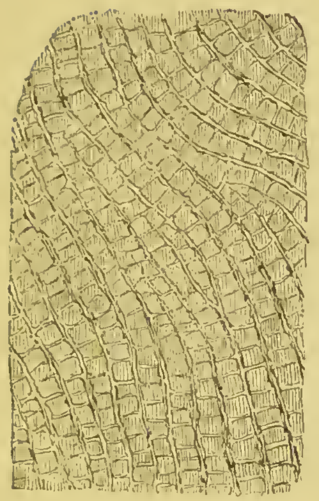
* *Dental Cosmos*, 1887.

"The method, as I have used it, is as follows: A freshly-extracted tooth, or one placed, immediately after its extraction, in dilute alcohol for a time, is ground, under water, as thin as practicable; then placed in a six per cent. solution of acetic acid, and left there for at least twelve hours even if the specimen be very thin, and for eighteen hours if slightly thicker; the acid is then poured off and the specimen repeatedly washed with distilled water, and then placed in a concentrated ammoniacal solution of carmin for twelve hours. After its removal from the carmin solution it is again washed with distilled water, and the enamel detached from the dentine with two needles. This process is easily accomplished, but a slight frill of the organic substance of the enamel is usually left attached to the dentine, and we obtain the enamel itself in small pieces. I have used two other reagents,—viz, a one-half per cent. solution of chloride of gold, and a one per cent. solution of hyperosmic acid. The specimens are subjected to the action of the former from twelve to twenty hours, and to the latter from one to three hours; after which they are carefully washed with distilled water; then treated with the acetic-acid solution as before stated. They are again washed; then mounted in glycerin, care being taken that they are not broken during this part of the process, their weakened condition from the action of the acetic acid having rendered them very brittle. Such a specimen, when viewed with a power of from 400 to 500 diameters, presents the following features: The enamel-rods are plainly recognizable (running their usual way, slightly wavy near the dentine, and straight toward the periphery), owing to the fact that the interstices between them are widened. Another feature presents itself which is quite striking,—viz, that the cross-bars within the enamel-rods also are widened, and plainly marked.

"We often meet with specimens of enamel where, toward the dentine, the rods are entirely lacking, or very indistinct, and much narrower than those a little distance from the dentine. Should the bundles of rods assume a fan-shaped appearance, as is sometimes seen in the neighborhood of the dentine, the interstices between such bundles may be found filled with a granular material, or with oblique or transverse sections of rods, occupying comparatively a small field. This latter appearance has undoubtedly led previous observers to conclude, and to make the statement, that the enamel is composed of interlacing bundles of rods. In a longitudinal section of enamel we find comparatively few transversely-cut bundles of rods, whereas obliquely-cut bundles are met with quite frequently. This fact leads to the conclusion that the appearance of interlacing is simply due to the presence of bundles of rods running in a more than usually wavy course, but never transversely to the general direction of the rods.

"The manner in which the acetic acid acts to produce the widening of the interstices, in my judgment, is as follows: In the process of grinding, the edges or borders of the rods are more or less exposed in every specimen, and probably the organic basis-substance is more or less disturbed. The edges being thus exposed to the action of the acid, the same as the ground surfaces of the rods, are dissolved away, and the interstices become widened, while the flat surfaces of the rods themselves are not perceptibly affected. This serves to explain also the widening and bringing so distinctly to view the 'cross-bars' in the rods, which also contain a minute amount of organic matter. Thin specimens of enamel treated with the same solution of acetic acid, if viewed with a power of from 500 to 600 diameters, clearly establish the above facts, since we can invariably trace all degrees of dissolution of lime-salts, from a slight widening of the interstices to the coarse granulation of the rods, then to the fine granulation, with the preservation of their general appearance, and finally down to their complete disappearance, nothing being left but the organic portion. The appearance in the field of the microscope is now very striking, it being finely granular, pale, and traversed by innumerable parallel filaments. Even moderately thick specimens may be utilized for bringing to view completely decalcified fields, by exerting a gentle pressure upon the covering-glass. I would not, however, recommend broken enamel-rods for microscopical research, as in my judgment such specimens are entirely worthless. I prefer to confine my studies to shreds in which either the traces of the previous rods are recognizable, or the fibers run a parallel and unbroken course. The foregoing description holds good for the majority of specimens of enamel. There are exceptions, however. Occasionally we find specimens with

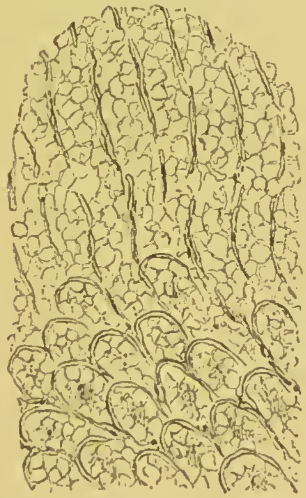
FIG. 58.



BEGINNING DECALCIFICATION OF ENAMEL, BY A SIX PER CENT. SOLUTION OF ACETIC ACID.

The interstices between the enamel-rods and the cross-bars of the rods widened. The rods exhibit slight organic structure, in consequence of the abundant presence of lime. Magnified 500 diameters.

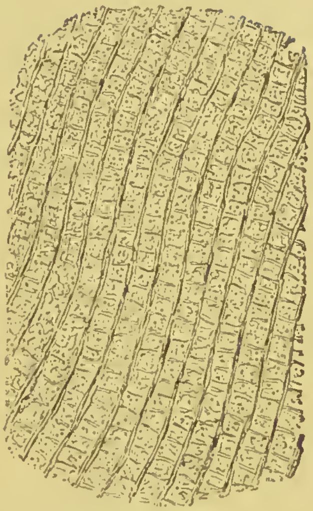
FIG. 60.



ENAMEL COMPLETELY DECALCIFIED, THROUGH THE AGENCY OF A SIX PER CENT. SOLUTION OF ACETIC ACID, SLIGHTLY STAINED WITH CHLORIDE OF GOLD.

The upper portion of the figure shows slightly oblique, and the lower very oblique, sections of the enamel-rods. The boundary lines of the prisms are made up of highly glistening elastic ledges, at the sides of which there are visible oblique sections of enamel-fibers in connection with a delicate grayish reticulum pervading the rods. This reticulum is especially dense in the central portion of the rods, as shown in the lower half of the figure. Magnified 1200 diameters.

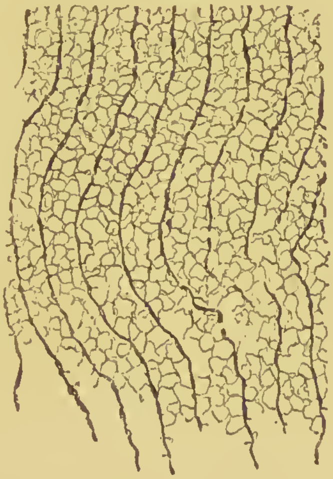
FIG. 59.



ADVANCED BUT NOT COMPLETE DECALCIFICATION OF ENAMEL, THROUGH THE AGENCY OF A SIX PER CENT. SOLUTION OF ACETIC ACID.

The interstices very marked, but not materially widened; their tenants, the enamel-fibers, plainly visible. The cross-bars do not appear in the shape of interstices, but in delicate transverse lines. The organic structure begins to appear, owing to partial removal of the lime-salts by solution. Magnified 500 diameters.

FIG. 61.



COMPLETELY DECALCIFIED ENAMEL DEEPLY STAINED WITH CHLORIDE OF GOLD.

The enamel-fibers appear in the shape of dark-violet, beaded threads, in connection with a grayish-blue reticulum within the enamel-rods. The transverse threads corresponding to the cross-bars are but slightly marked. In the lower portion of the figure the reticulum is partly torn away, leaving the enamel-fibers protruding and rendered plainly visible. Magnified 1200 diameters.

unusually narrow prisms, or perhaps lacking them altogether, in comparatively large districts. Whether this feature is due to advanced age, malformation, or some pathological condition, I am unable to say. The higher powers of the microscope (1200 to 1500 diameters) give a highly gratifying image of the structure of enamel. Partially decalcified rods appear to be composed of irregular lumps, of high refraction, invariably arranged in the shape of irregular squares, which serve to complete the rods; the irregular interstices separating the glossy lumps are traversed by delicate grayish threads. The interstices causing the appearance of cross-bars through the rods are traversed by minute grayish, beaded filaments, sending offshoots into the fields of the rods between them. The longitudinal interstices between the enamel-rods, in many places, show long, beaded filaments, on either side of which we observe a light space. This space again is traversed by conical threads arising from the enamel-fibers, and penetrating the interior of the rods themselves.

"In thoroughly decalcified enamel, I have often met with a peculiar appearance. Whether carmin, chloride of gold, or osmic acid had been used for staining the specimen is immaterial,—the rods appear to be surrounded by a glossy, smooth, or beaded border, between which can be seen the light interstices. Sometimes there is one such ledge for two neighboring rods, without any intervening interstice. In oblique sections the ledges are best marked on the distal portions of the rods, overlapping their neighbors in a shingle-like manner; while in transverse sections the glossy border may be seen all around the rods. It is evident that these ledges cannot be mistaken for the enamel-fibers proper; nor can we conclude that the ledge is an optical phenomenon, caused, as it were, by the thickness of the rods, since the ledge is often found slightly protruding beyond the border of the specimen. The only explanation I can suggest for this is that the borders of the rods are made of a denser kind of basis-substance, kindred to the elastic substance, and similar to that which we observe in the basis-substance of the dentine surrounding the canaliculi. In the center of the rod we not infrequently see a somewhat more compact accumulation of a pale gray substance than in the rest of the rod.

"Completely decalcified portions of the enamel exhibit a most beautiful reticulum, especially in specimens treated with chloride of gold, and not the least doubt can arise as to the fact that the enamel-fibers, being the most conspicuous formations, are in an uninterrupted continuity with the reticulum of living matter pervading the whole enamel."

CHAPTER XII.

THE MINUTE STRUCTURE OF CEMENTUM.*

The zone of dentine is not continuous everywhere about the pulp-cavity. Around the apices of the roots the cementum, although the outermost layer of the tooth, immediately lines the cavity.

In the cementum delicate parallel striations are to be seen, identical with the lamellæ of a Haversian system, and, as a rule, more plainly marked near the periphery than near the dentine. The lamellæ exhibit a more or less concentrical arrangement around the pulp-cavity, easily demonstrable on cross-sections.

Within the basis-substance of the cementum there are numerous branching spaces, in correspondence with the lacunæ of bone. The offshoots of these spaces in the cementum, like the spaces themselves, are very marked in dry specimens, because of their being filled with air. In chromic-acid specimens, on the contrary, the offshoots are much less prominent, and the less so the more thoroughly the decalcification has been effected by the acid. No essential difference is noticeable in the lacunæ and canaliculi of ordinary bone from those of the cementum; in both tissues there exists great variety in the general arrangement, in the size of the lacunæ, and in the number and ramifications of their offshoots.

The walls of the lacunæ and the coarser offshoots, if viewed with a highly magnifying lens (immersion 1000 to 1500 diam.), appear interrupted at their peripheries by light openings, which lead into a light, delicate net-work, piercing the whole basis-substance to such an extent that the meshes have to be considered only as fields of calcified glue-yielding basis-substance.

Each lacuna contains a protoplasmic body, with a central nucleus,—the cement-corpuscle. The nucleus sometimes is relatively large, and surrounded only by a narrow seam of protoplasm; while in some small lacunæ a body of the appearance of a nucleus is present without a noticeable amount of surrounding protoplasm. The net-like structure of both the nuclei and the protoplasm is plainly visible in all cement-corpuscles. From the periphery of each corpuscle arise conical offshoots, of which the coarser ones penetrate into the larger offshoots of the lacuna, while the finest offshoots of the protoplasm traverse the light rim between the wall of the lacuna and the periphery of the protoplasm, being directed toward a light interruption on the boundary of the lacuna.

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* "The Distribution of Living Matter in Human Dentine, Cement, and Enamel." *Dental Cosmos*, 1878–1879.

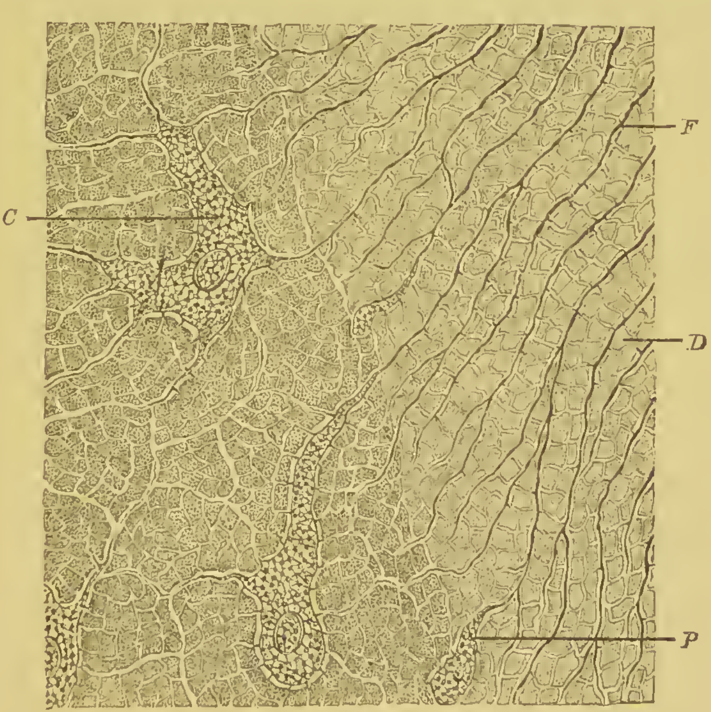
Cement-corpuscles, on the average, are round or spindle-shaped bodies, the long diameter of which corresponds to the direction of the lamellæ. In the teeth of juvenile and middle-aged persons we meet with cement-corpuscles three or four times surpassing the size of ordinary ones, in which two or three nuclei are visible. Instead of multinuclear bodies, a number of medullary nucleated elements may fill a large lacuna, all these elements being connected with one another by very delicate threads. The longitudinal diameter of such large lacunæ is sometimes, therefore, an axis from which those elements radiate vertically to the direction of the lamellæ.

Numerous cement-corpuscles send broad and branching offshoots through the basis-substance in a direction perpendicular or oblique to the lamellæ, and not infrequently a direct union is established between two or three cement-corpuscles by means of such large offshoots. (Fig. 42, page 73.)

In some teeth broad, spindle-shaped spaces pierce the cementum radiately, all of them containing protoplasm with delicate offshoots directed toward the net-work in the basis-substance. Nay, sometimes medullary spaces traverse the lamellæ in different directions, which spaces contain, besides a varying number of medullary elements, capillary blood-vessels evidently in connection with the capillaries of the pericementum. These formations may be considered as remnants of the embryonic condition of the cementum, and are never present in large numbers. All protoplasmic formations within the cementum, though greatly varying in shape, are alike in being connected with one another by the delicate net-work that pierces the basis-substance.

At the periphery of the cementum, on the line of its connection with the pericementum, the net-work of the protoplasm is usually very broad, and the fields of the basis-substance show a prevailing globular appearance. Also numerous spindle-shaped protoplasmic bodies are seen in connection with the cementum in an oblique arrangement, forming the transition into the structure of the pericementum. Between the calcified cementum and the striated connective tissue of the pericementum there often exists a narrow zone, occupied by closely-packed spindle-shaped protoplasmic bodies only. In the pericementum itself there are less numerous, partly nucleated protoplasmic bodies, between which the fields of an apparently homogeneous glue-yielding substance are seen. (See Fig. 62.)

FIG. 62.



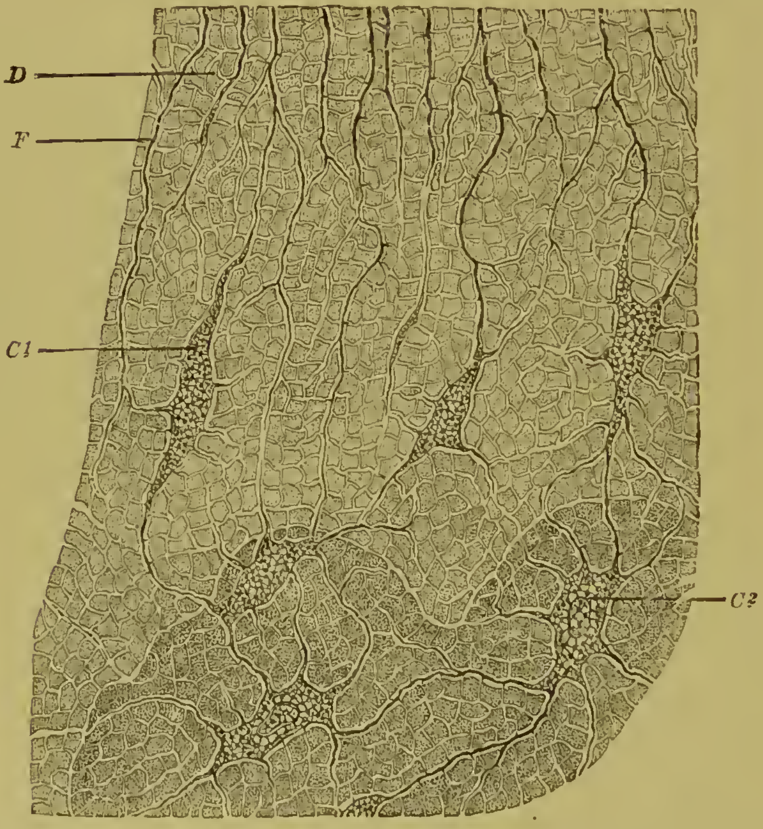
TRANSITION OF DENTINE INTO CEMENTUM, WITHOUT A MARKED BOUNDARY.

C, branching cement-corpuscle; *P*, spindle-shaped cement-corpuscle; both in direct connection with dentinal fibers, *F*, which bifurcate within the canaliculi of the dentine, *D*. Magnified 1200 diameters.

The connection between dentine and cementum is established either by a gradual change of one tissue into the other, without a distinct line of demarcation, or there exists a boundary formed by a more or less marked wavy line, presenting irregular bay-like excavations. Lastly, it occurs that between the bay-like excavations and the dentine there is interposed a stratum of the structure of cementum, with a gradual change of the tissue of the former into that of the latter. (See Fig. 63.)

Where a gradual change takes place, the dentinal canaliculi show irregular, mainly spindle-shaped enlargements, which stand in the direction of the dentinal canaliculi themselves, or run obliquely through the basis-substance of the cementum. The distal end of such a spindle is, as a rule, in connection with a regular lacuna of the cementum, or with an analogous formation of a neighboring dentinal canaliculus. Many of the latter simply pass into the light, delicate net-work characteristic of the basis-substance of cementum. The dentinal fiber is in direct union with the protoplasm, which fills the spindle-shaped spaces, or it is lost to sight upon entering the net-work of the basis-substance of the cementum.

Fig. 63.



Transition of Dentine into Cement, with an Intermediate Layer of Cement-structure.

D, dentine; *F*, bifurcating dentine-fibers, in union with elongated cement-corpuscles, C^1: these are imbedded in a basis-substance blending with that of dentine. The regular cementum is characterized by branching corpuscles, C^2. Magnified 1200 diameters.

Where a boundary with bay-like excavations is present between dentine and cementum, spindle-shaped enlargements of the dentinal canaliculi may be seen, much smaller than in the former instance. The majority of the dentinal canaliculi, however, reach the boundary of the cementum after repeated bifurcations, by which the caliber both of the canaliculi and of their central fibers is gradually diminished.

A connection of the dentinal fibers with the coarser offshoots of the cement-corpuscles is often observed. The light net-work of the basis-substance of the dentine always passes into that of the cementum. Not rarely, also, on the bottom of a bay-like excavation, partly nucleated protoplasmic bodies are present, into which the dentinal fibers inosculate. The connection between these and the coarser offshoots of the cement-corpuscles under these circumstances is established by such intervening protoplasmic bodies.

The Neck of the Tooth.—There are certain peculiarities about the minute anatomy of the neck of the human tooth which, so far as I can judge from the literature within my reach, have not heretofore been mentioned.

John Tomes* in describing the distribution of the dentinal tubes, says, "Near the neck they stop short of the cementum."

This assertion is in accord with the writer's observations. In the great majority of teeth neither the canaliculi nor their tenants, the dentinal fibers, reach that part of the cementum which surrounds the neck. Near the periphery of the dentine bifurcations of the canaliculi—and consequently also of their tenants, the dentinal fibers—take place, some of the finest terminations of which run to the boundary between the dentine and cementum. As a rule the finest terminations of these fibers are lost to sight in a net-work somewhat coarser than that of the basis-substance of ordinary dentine. The minute elongations of the dentinal fibers can also be traced into the light network with more distinctness than elsewhere in the dentine. Sometimes the dentinal canaliculi, upon approaching the periphery, become slightly dilated so as to produce slender pear-shaped cavities, in accordance with which the terminating dentinal fibers exhibit slight enlargements.

The boundary between dentine and cementum presents a wavy line, traversed by delicate threads, or occupied by spindle-shaped protoplasmic formations, all of which are in union with direct or indirect elongations of the dentinal fibers.

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* "System of Dental Surgery," 1873.

The cementum around the neck forms a narrow layer, which is cut off obliquely at the place of junction with the enamel. Both the cementum and enamel in this situation—being of the same width—are separated by a boundary which runs from the outer periphery obliquely downward to the dentine. This relation I found in the majority of teeth, and it is only exceptionally that I have met with cementum regularly overlapping the enamel. The cementum on the neck is built up of delicate prisms, or spindles, arranged vertically to the surface of the dentine. The prisms represent the fields of the basis-substance, and are separated from one another by light rims, holding beaded fibers, or traversed by delicate vertical threads. In transverse sections, when the prisms are cut obliquely, they exhibit irregular opaque fields separated from one another by light rims.

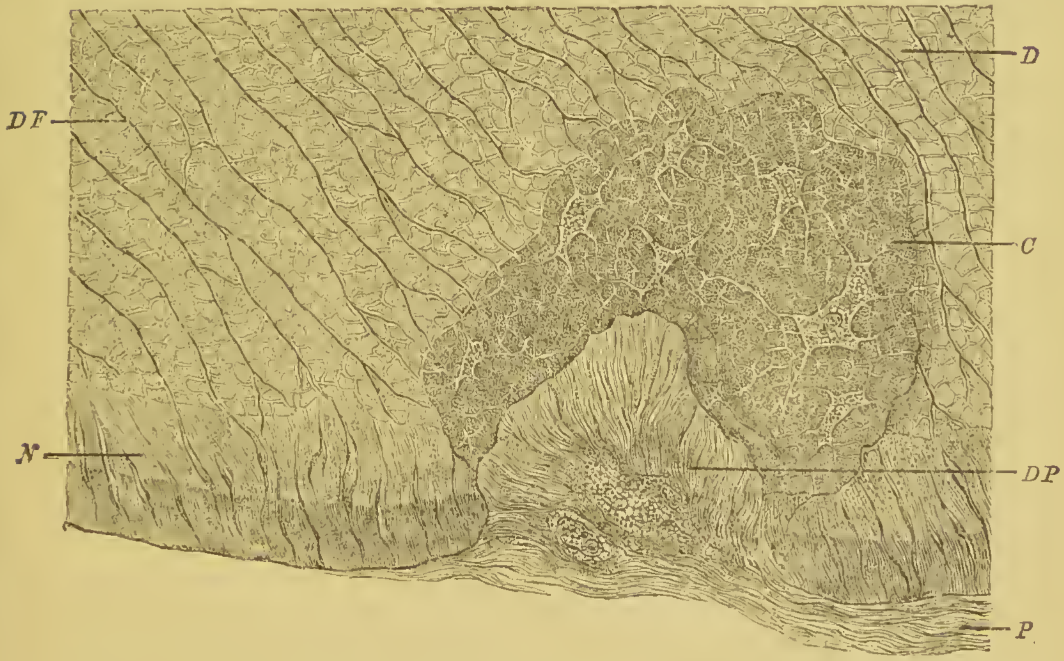
These formations closely resemble the protoplasmic bodies of the pericementum next to the cementum, alluded to in the former chapter; hence I do not hesitate to consider the bony formation on the neck as being produced by calcification of the osteoblasts of the pericementum. The cementum on the neck of the tooth is devoid of lamellæ and lacunæ, which appear deeper below, together with all the characteristic features of the fully-developed structure of the cementum. The lamellæ become the more distinct, and the lacunæ, with their contents (the cement-corpuscles), the more numerous, the broader the diameter of the layer of the cementum.

The outer surface of the cementum is covered on its upper part with epithelial elements closely resembling those of Nasmyth's layer of the enamel. This layer turns over into the epithelial coat of the gum. Farther down, the cementum, though still endowed with properties characteristic of the neck of the tooth, is surrounded by the fibrous connective tissue of the pericementum.

I have met in one instance with striking formations on the neck of a tooth, which I consider anomalous, but not quite pathological. Here the ordinary cement of the neck is interrupted by grooves or pits containing the elements of pericemental tissue. The inner periphery of the pit is covered with a well-developed, evidently isolated formation of cementum. The island of the cementum is broadest above the bottom of the pit, and slopes down along the walls of the pit, until it is lost within the layer of the cementum of the neck. (See Fig. 64.)

Results.—The cementum, as well as ordinary bone, is provided with lacunæ and canaliculi. The lacunæ contain nucleated protoplasmic bodies, and the canaliculi hold offshoots of the living matter of the protoplasm. The whole basis-substance of the cementum is traversed by a delicate net-work, which in all probability contains living matter, though this is traceable only in its thorn-like projections from the periphery of the protoplasm and its larger offshoots. The living matter of the cementum is uninterruptedly connected with that of the periosteum, and continuous with the living matter of the dentine, either through intervening protoplasmic bodies in the interzonal layer, or directly with the dentinal fibers.

Fig. 64.



Anomalous Formation of Cementum on the Neck of a Human Tooth.

D, dentine; *DF*, dentinal fibrillæ; *N*, cementum on neck of tooth, with spindle-shaped or prismatic fields of basis-substance; *DP*, depression in the cementum of the neck, filled with elements of pericementum surrounded superiorly by a zone of regularly developed cementum, *C*; *P*, pericementum. Magnified 1200 diameters.

The cementum covering the neck of the tooth is devoid of lamellæ and protoplasmic bodies. It is built up of directly calcified osteoblasts of the pericementum, presenting their prismatic shapes, and everywhere traversed by a net-work of living matter.

This is in connection either with the epithelium of Nasmyth's layer or the pericementum, and with the dentine mainly through the intervening net-work in the basis-substance of the latter.

Investigations concerning the structure of the cementum have been published by Carl Heitzmann and F. A. Roy,* of which I offer the following:

"**Method.**—A recommendable method for the study of the microscopical structure of the cementum is to grind a tooth as thin as possible, always keeping it moist with a one per cent. solution of table-salt. First, with a fine saw or with a corundum-stone in the lathe, a coarse slab is made of the freshly-extracted tooth, which afterward is ground thin on a corundum-slab, and finished on an Arkansas stone. The specimen is not allowed to become dry for a moment. After brushing away the *débris* from grinding, the specimen is directly mounted in chemically-pure glycerin, or staining with ammoniacal carmin may be resorted to, though such a stain is of comparatively little value in the study of cementum. Some of our illustrations are made from specimens prepared in the manner just described. They are especially plain when examined immediately after mounting, but rarely fit for higher powers of the microscope,—powers exceeding from 500 to 600 diameters. After several weeks, when the glycerin has thoroughly saturated the specimen, the minute features are, as a rule, less conspicuous than in the freshly-mounted specimen.

"The method first employed by William Carr, in 1889, for bringing to view the minutest structure of the dentine, is a protracted stain with a one-half of one per cent. solution of chloride of gold, of plates ground thin with the finger on grinding-stones and corundum-slabs, and a subsequent complete decalcification by means of a six per cent. solution of glacial acetic acid. This method has also enabled John I. Hart to obtain perfect specimens of dentine. The same procedure we have adopted for clearing up the minutest features in the structure of the cementum. Freshly-extracted teeth are placed in a one per cent. solution of table-salt and ground thin, as before stated. It is important to leave the extracted teeth a short time only in the salt solution,—a few hours at the utmost,—since the protoplasmic formations of the cementum become hydropic and unstainable with chloride of gold if left in the solution for days. This tissue, being directly exposed to the salt solution, is affected by it sooner than the dentine. Special care must be taken in keeping the slabs moist with a weak solution of table-salt, lest the specimen become dry, and the lacunæ and the coarser canaliculi filled with air, by which the details are rendered indistinct, or obliterated completely. After the slab—immaterial whether a longitudinal or a transverse section—has attained a sufficient degree of thinness, as proven by mounting on a slide and covering with the thinnest possible covering-glass, it must be washed carefully and repeatedly with a camel's-hair brush, under continuous renewal of the salt solution. Next the slab is placed in a one-half of one per cent. solution of chloride of gold, in which process all metallic instruments must be avoided, the simplest spatula being a match shaped with a penknife. If several sections should be ready for treatment with chloride of gold, it is necessary to see that each one be in free contact with the gold solution. Specimens overlapping one another prevent a perfect stain, because they will not allow the desired contact and penetration with the gold solution."

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* Transactions of the New York Odontological Society, 1892.

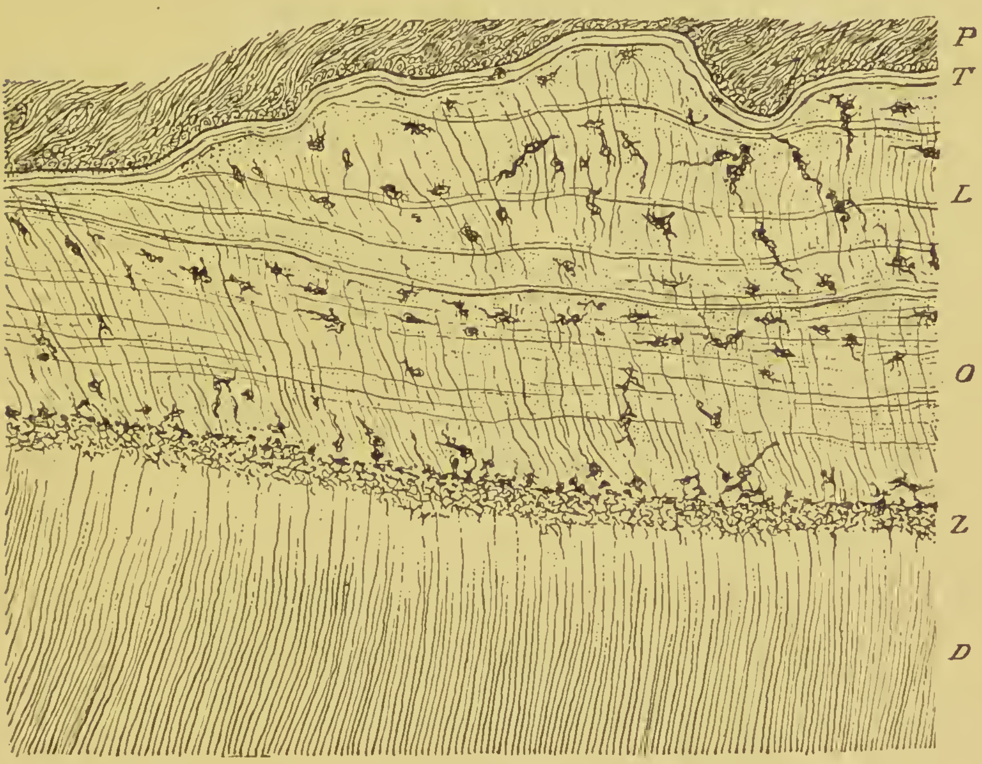
"The time required for exposure to the gold-salt is somewhat different with different teeth, probably because of the variable amount of lime-salts infiltrating the cementum. The best results we have obtained were on temporary teeth left in the gold solution from six to seven hours,—certainly a shorter time than is required for staining the dentine. The following exposure for ten hours to a six per cent. solution of glacial acetic acid is, as a rule, sufficient for complete decalcification of the cementum, and now the specimen may be exposed to broad daylight for a number of days, until it has assumed a dark-violet or dark-purple color. The only precaution required at this stage of the procedure is to renew every day the distilled water in which the specimen lies, in order to prevent the growth of mildew. A drop of chemically-pure glycerin added to the distilled water is a sure means of keeping away the mildew. The mounting of such specimens is invariably done in glycerin,—the only medium which allows the examination with the highest powers of the microscope.

"We admit that the results obtained in the described manner of treating cementum were not uniformly satisfactory, in contradistinction to those in the preparation of dentine, in which failures are exceptional. We cannot account for the fact that specimens of different teeth which we knew to be alive and perfectly fresh, yielded good images only occasionally. Cohnheim, the discoverer of the gold-stain, met with the same accidents. Sometimes the basis-substance assumes a deeper color than the contents of the lacunæ; the latter may remain so pale even as to imitate features of devitalized teeth. Specimens well stained, however, exhibited all features so handsomely that we thought best to describe this method, leaving the invention of new procedures to other observers. It is especially the acetic acid which we suspect of yielding unsatisfactory results, and other acids—perhaps diluted sulphuric acid—may have to be resorted to in future trials. Owing to the unequal efficiency of the method employed, we will abstain from statements which are of the utmost importance to the practitioner,—viz, the definition of the living from the non-living part of the cementum in pulpless teeth. The results of our examination seem to be sufficiently interesting, however, so far as they go, to deserve presentation.

" **Cement of the Roots.**—We have examined quite a number of roots of teeth, both deciduous and permanent, in specimens ground thin under the protection of an indifferent liquid,—a one per cent. solution of table-salt. Our intention has been to study the features of the cement-tissue in freshly-ground specimens, before they were exposed to the influence of a solution of chloride of gold. What we saw in many instances has not up to this time been described. (See Fig. 65.)

" With low powers of the microscope, we find on the surface of the cementum shallow pits that render the border-line, in a longitudinal section, hilly or wavy. This corresponds to the rough, slightly-pitted aspect of the surface of the roots, viewed with the naked eye. The lamellated portion of the cement tapers toward the neck of the tooth, and becomes the broader as it approaches the apices of the roots. In this portion of the cement-tissue the parallel lamellæ are conspicuous, and we notice scattered in the basis-substance a number of cement-corpuscles which differ from ordinary bone-corpuscles only in being more irregular, often elongated, apparently arranged without regularity, certainly without parallelism to the lamellæ. Besides the cement-corpuscles, we notice a number of lines running from the surface to the dentine, and piercing the lamellæ at right or acute angles, often in union with the cement-corpuscles. The course taken by these lines, which in their parallelism bear somewhat the aspect of dentinal fibers, is always devious from the latter, with which they produce obtuse angles. We have failed to find an immediate union of dentinal fibers with the fibers piercing the cementum. The lamellated portion is followed by a layer, indistinctly lamellated or striated, likewise containing cement-corpuscles, and likewise traversed by radiating lines. This layer, either indistinctly lamellated or entirely destitute of lamellæ, we propose to term 'the osteoid layer of the cementum.' At the boundary of the osteoid layer, toward

Fig. 65.



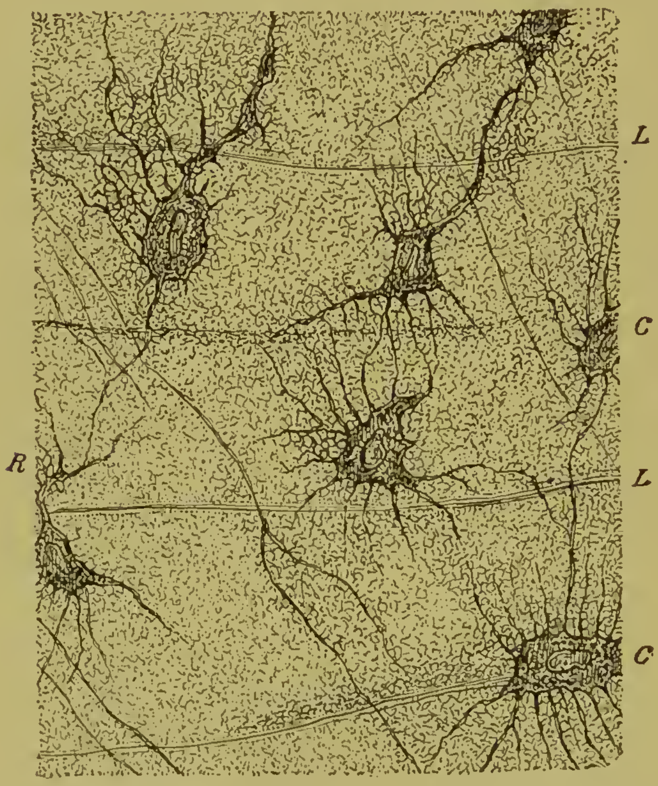
Root of a Ground Bicuspid, showing a Combination of Lamellated and Osteoid Cementum.

P, pericementum; *T*, thickness of the specimen; *L*, lamellated cementum; *O*, osteoid cementum; *Z*, interzonal layer between cementum and dentine; *D*, dentine. Magnified 200 diameters.

the dentine, a layer of numerous small protoplasmic bodies is seen in our specimen, similar to those of an ill-calcified enamel, and probably due to a deficient calcification of the cementum. This layer is rather exceptional. The dentinal canaliculi either stop short of the interzonal osteoid layer, or a limited number of canaliculi is seen to directly run into the interzonal layer, where they inosculate with the coarse protoplasmic reticulum.

"The aspect of the cement-corpuscles in the distinctly lamellated portion is rather peculiar in ground specimens, mounted in glycerin, when viewed with medium powers of the microscope, 500 to 600 diameters. The lacunæ appear filled with protoplasmic bodies, in the center of which we notice oblong nuclei. From the periphery of the bodies numerous offshoots break forth, which either directly connect neighboring cement-corpuscles, or are lost in the basis-substance. Innumerable fine offshoots are seen to emanate from the coarse ones, and by these finest offshoots an indistinct net-work is established, particularly plain in the vicinity of the cement-corpuscles. The basis-substance appears coarsely granular, but no reticulum proper can be made out with this amplification. The basis-substance is pierced by peculiar fibers which intersect the lamellæ at right or acute angles, often are bifurcate, and in many instances are independent of the cement-corpuscles or their offshoots, while in other instances they distinctly inosculate with the two last-named formations. (See Fig. 66.)

Fig. 66.



Lamellated Cementum of the Root of a Ground Bicuspid.

C, C, cement-corpuscles branching and interconnecting; *R,* incomplete reticulum, produced by the finest offshoots of the cement-corpuscles; *L, L,* boundary-lines of the lamellæ. Magnified 600 diameters.

"The question arises, What are these fibers in the cementum? The first idea suggesting itself is that we have to deal with perforating fibers, first described by Sharpey in specimens of dry bone-tissue. Charles S. Tomes* says, 'Like bone, cementum is also sometimes found to contain Sharpey's fibers; that is to say, rods running through it at right angles to its own lamination, and, as it were, perforating it. These are probably calcified bundles of connective tissue.'

"Sharpey's fibers are never seen in specimens decalcified by solutions of chromic acid. Histologists assert that they are elastic fibers, not perishable after treatment of the specimen with caustic potash. The fibers in the cementum, on the contrary, are canaliculi in the basis-substance, holding protoplasm, or rather living matter, which feature renders them akin to dentinal fibers. We propose the name of 'piercing cement-fibrillæ' for their designation.

"The ultimate analysis of the tissue of cementum is possible only after exposure to a solution of chloride of gold and subsequent decalcification with acetic acid. (See Fig. 67.)

"We see the cement-corpuscles, the nuclei of which often appear a trifle lighter than the rest of the protoplasm. The reticular structure of the latter is plain in many corpuscles. Numerous coarse and innumerable fine offshoots break forth from the periphery of the cement-corpuscles. Close around the latter and their coarse offshoots a light rim is present, traversed by the minutest conical offshoots, which rim obviously corresponds to the wall of the lacunæ and canaliculi. The walls are rendered indistinct by the decalcification of the specimen. The whole basis-substance is traversed by an extremely minute reticulum of a dark-violet color, interconnecting all cement-corpuscles. The behavior of this reticulum toward chloride of gold clears up the nature of it: living matter produces the network in the protoplasm, as well as in the basis-substance. Of this reticulum, however, the meshes must be considered as the basis-substance proper, composed of what we term glue or gelatin, and saturated with lime-salts. The boundary zone or interzonal layer between dentine and cementum is conspicuous by its bay-like excavations. In this region we easily recognize the union of most of the dentinal fibers with coarser offshoots of the cement-corpuscles,—a fact already established by Bödecker. An immediate union of the living matter of the dentine with that of the cementum is fairly plain, since from six to eight hours' exposure to the solution of chloride of gold was sufficient to bring to view the reticulum in the cementum, whereas ten hours' exposure is needed, according to John I. Hart, to stain the reticulum of the dentine to a satisfactory degree. No doubt, in a living tooth, the whole cementum is a tissue, endowed with properties of life, the same as is dentine. Life is not confined to the cement-corpuscles and their coarser offshoots, but extends all through the basis-substance, being active within the reticulum that pervades the protoplasm; and active also within that of the basis-substance. The study of the pathology of cementum has furnished ample proof for the corroboration of this statement.

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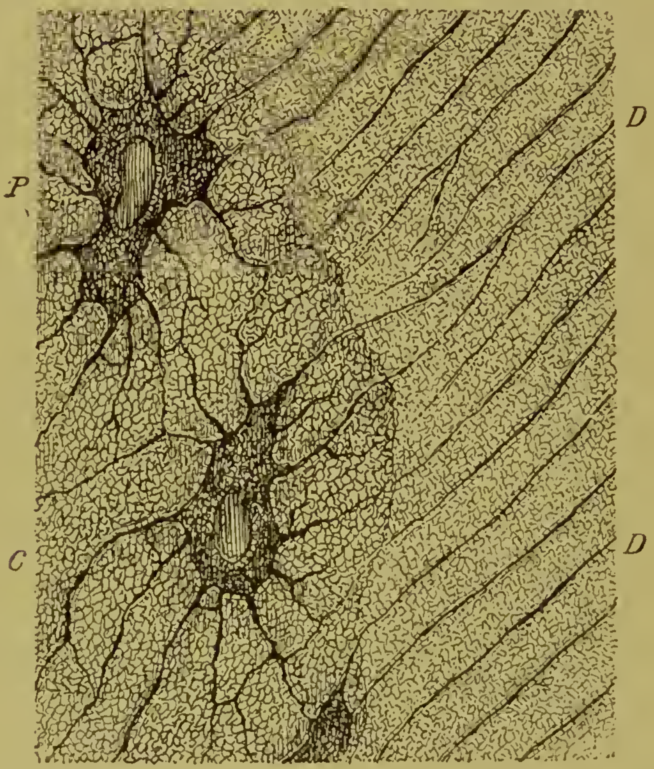
* "A Manual of Dental Anatomy." Philadelphia, 1876.

Fig. 67.



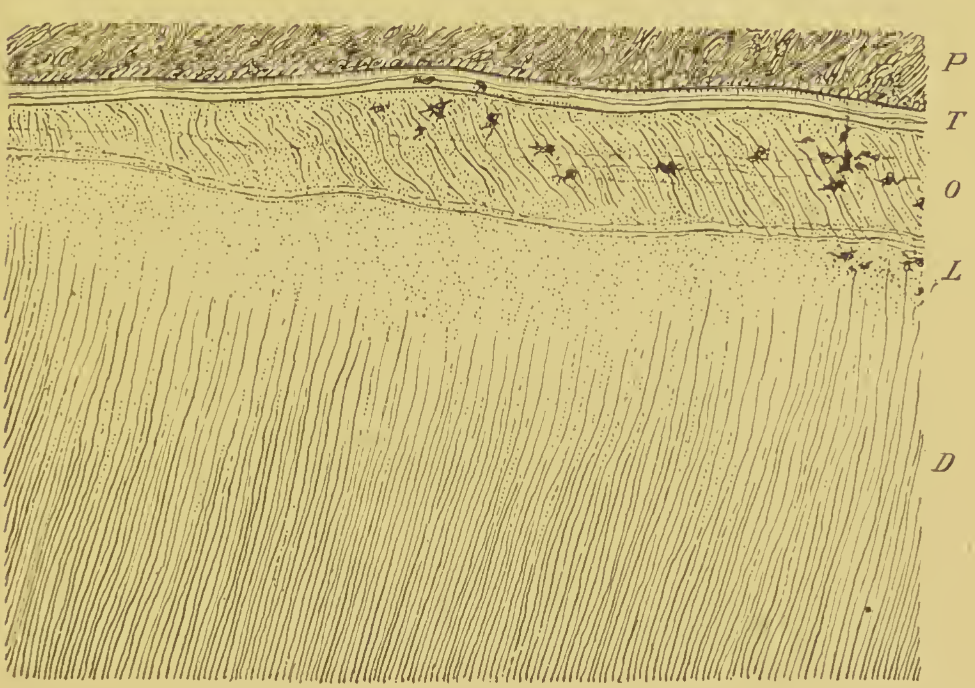
Root of a Molar in Longitudinal Section. Stained with Chloride of Gold.

P, nucleated protoplasmic body with coarse, dark-violet offshoots; *C*, basis-substance of cementum, pierced by a violet delicate reticulum; *D*, *D*, dentine. Most of the dentinal fibers unite with offshoots of cement-corpuscles. Magnified 1200 diameters.

"**Osteoid Cementum.**—The tissue of the cementum covering the neck of the tooth is different in its microscopical structure from the main mass of the cementum. It is known that the thin layer of this tissue gradually blends with the cementum proper. First the prisms of the neck-layer disappear, and a granular layer makes its appearance, destitute, as yet, of lamellæ and cement-corpuscles, exhibiting a few faint striations, and traversed, as in our specimen, occasionally, though not always, by piercing cement-fibrillæ. (See Fig. 68.)

"This formation is probably what Charles S. Tomes* describes in the following words: 'The matrix of the cementum is sometimes apparently structureless, at others finely granular or interspersed with small globules.' We wish to term it the 'osteoid layer' of the cementum. By the name 'osteoid' the histologists designate a tissue kindred to bone, saturated with lime-salts, lacking bone-corpuscles or showing but few of them, and without lamellæ. All this characterization holds good for the portion of the cementum under consideration. Its history

FIG. 68.



ROOT OF A GROUND BICUSPID IN LONGITUDINAL SECTION. TRANSITION OF THE CEMENTUM OF THE NECK INTO THAT OF THE ROOT.

P, pericementum; *T*, thickness of the specimen; *O*, osteoid layer of the cementum; *D*, dentine: *L*, protoplasmic bodies at the interzonal layer between dentine and cementum. Magnified 200 diameters.

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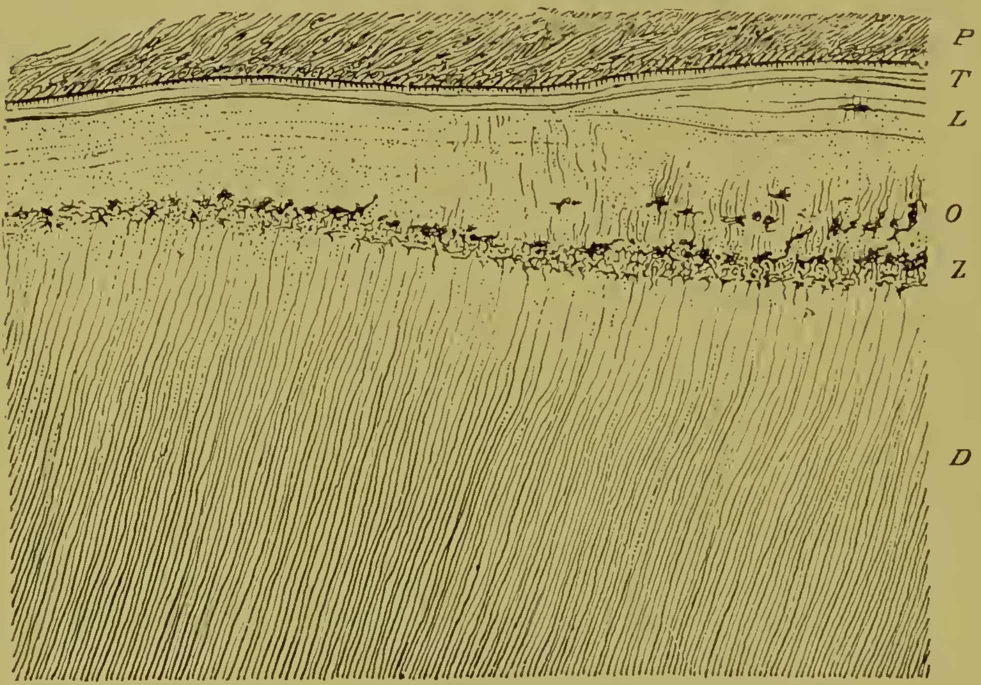
* "A Manual of Dental Anatomy." Philadelphia, 1876.

of development will be cleared up some day, when the development of cementum will be studied in human teeth,—a study not as yet accomplished.

"The osteoid layer shows, as it nears the lamellated cementum, a few irregular bone-corpuscles. The lamellated portion starts from the periphery of the root, and soon becomes broader and supplied with regular, freely-branching cement-corpuscles, with the result that the osteoid structure, in the majority of the teeth examined, is lost to sight. In the specimen from which the illustration is taken, the dentinal fibrillæ stop short of the osteoid layer, a feature so characteristic of the anatomy of the neck. Near the interzonal layer, between the dentine and the osteoid tissue, a few small protoplasmic bodies are seen, into which dentinal fibers inosculate.

Fig. 69.

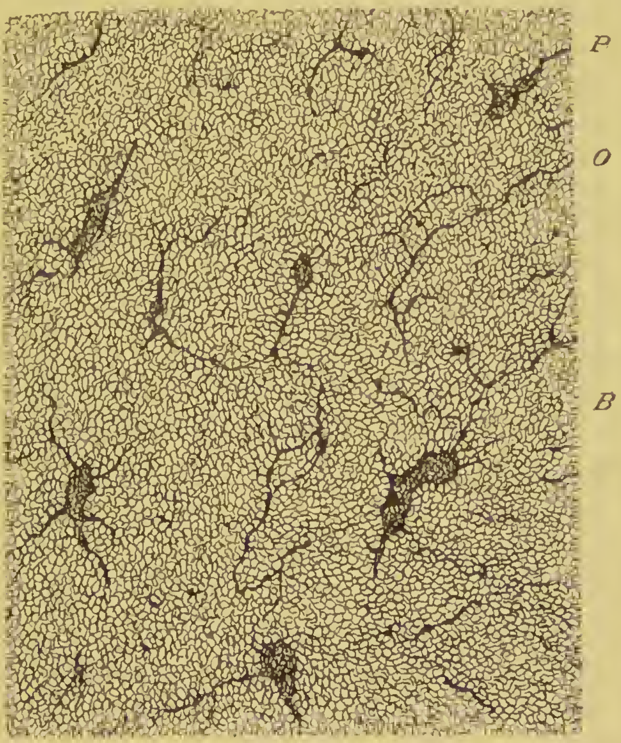


Root of a Ground Molar in Longitudinal Section. Transition of Osteoid into Lamellated Cementum.

P, pericementum; *T*, thickness of the specimen; *L*, lamellated cementum; *O*, *osteoid cementum*; *Z*, interzonal layer between dentine and cementum; *D*, dentine. Magnified 200 diameters.

"Not infrequently the osteoid layer does not perish, even though lamellated cementum has made its appearance; nay, the osteoid layer may be seen all around the root, as an intervening formation between dentine and cementum. Fig. 69 is taken from such a specimen. Here we see the beginning of a lamellated formation, between which and the dentine are protoplasmic bodies, with a number of long and parallel offshoots, of the aspect of piercing fibers. The interzonal layer, in this instance, is conspicuous by a large number of interconnecting protoplasmic bodies, in union on their upward course with cement-corpuscles, and on their downward course with dentinal fibers. This peculiar formation is traccable all along the roots, and signifies an incomplete deposition of lime-salts at the time of the formation of the cementum. The dentine of this tooth is fully developed, lacking even the so-called interglobular spaces in the crown.

Fig. 70.



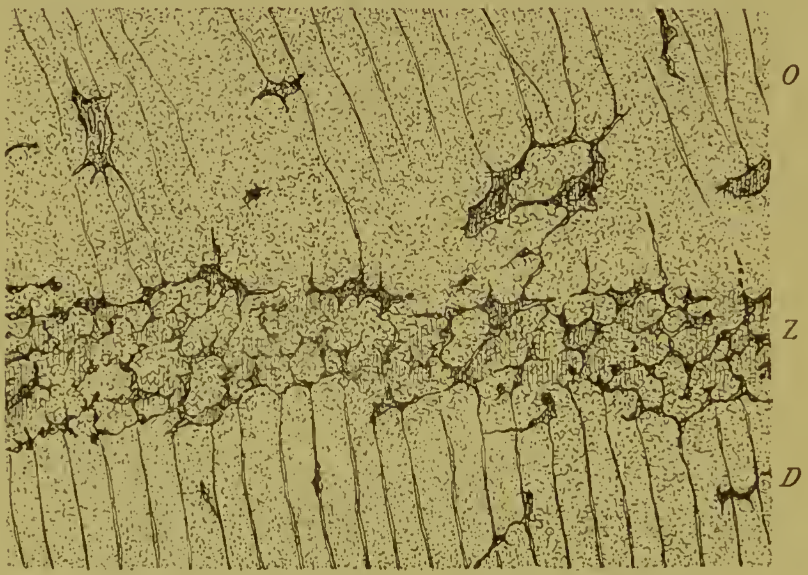
Osteoid Layer of the Root of an Incisor. Longitudinal Section. Stained with Chloride of Gold.

P, protoplasmic body, with scanty, coarse offshoots; *O*, coarse offshoot, apparently in no connection with a protoplasmic body; *B*, basis-substance of the osteoid layer, traversed by a delicate reticulum. Magnified 1200 diameters.

" In order more thoroughly to understand the structure of the osteoid layer, we have applied to such specimens the protracted gold stain, with subsequent decalcification by means of diluted acetic acid; the image thus obtained was a striking one indeed. (See Fig. 70.)

"We observe small, odd-shaped protoplasmic bodies of a dark-violet color, exhibiting but a limited number of coarse offshoots. Besides, coarse dark-violet fibers traverse the basis-substance, making a coarse net-work, arranged without apparent regularity, and also, as it seems, lacking connections with larger protoplasmic masses. This latter feature may be due to a curved course of the fibers, the union with cement-corpuscles being severed by the process of grinding. The whole basis-substance is seen to be traversed by a, comparatively speaking, coarse, dark-violet reticulum, in union with the protoplasmic bodies, as well as with the coarse fibers. Unquestionably the reticulum is the living matter proper, which endows the osteoid layer with a considerable degree of vitality and sensibility.

Fig. 71.



Osteoid Cementum of the Root of a Ground Bicuspid.

O, osteoid layer of the cementum, with scanty protoplasmic bodies and piercing cement-fibrillæ; *Z*, interzonal layer between dentine and cementum, with numerous branching protoplasmic formations; *D*, dentine with scanty protoplasmic bodies. Magnified 600 diameters.

"The peculiar interzonal formations, represented in Fig. 69, we have also examined with higher powers of the microscope. (See Fig. 71.)

"We notice small protoplasmic bodies branching and interconnecting. Upward their offshoots run into cement-corpuscles, or into piercing fibers of the cementum, whereas, downward the offshoots blend with the dentinal fibers. Even the dentine is possessed of protoplasmic formations, a certain distance away from the interzonal layer; all of which proves a deficient calcification just at the time of the beginning of the development of the cementum. The specimen from which the drawing is made was not stained with chloride of gold, and not decalcified; hence the reticulum of the basis-substance is only indicated, not conspicuous. No doubt, however, can arise about its presence.

"**Cementum of the Neck.**—Bödecker was the first to accurately describe the minute anatomical features of the cementum of the neck. How defective the knowledge of this region was, even sixteen years ago, is best shown by a quotation from Charles S. Tomes, who says,* 'Where the cementum is very thin, as for instance, where it commences at the neck of a human tooth, it is to all appearance structureless, and does not contain any lacunæ.' The cementum of the neck, as is well known, forms an extremely thin layer, sharply bordered toward the enamel, and sometimes even overlapping the latter. Bödecker speaks of directly calcified prisms in the neck-cementum, which, in his opinion, may be considered as osteoblasts, infiltrated with lime-salts. Sometimes the prismatic structure is not pronounced, but a row of spindles is seen arranged in a direction almost perpendicular to the surface of the tooth. Larger and smaller spindles alternate, the latter sometimes being so small as to convey the impression of fibers.

"There is a slight discrepancy between the statements of Bödecker and our own observations. We fully concur with him as to the calcified prisms; but the spindles, sometimes very conspicuous even to medium powers of the microscope, we cannot consider as formations of the basis-substance. Rather, we should regard the spindles and alternating fibers as protoplasmic formations, which fill the interstices between the prismatic pieces of the cementum of the neck. This tissue, in our opinion, is either composed of prisms alone, with intervening light and parallel spaces, or of prisms, between which are protoplasmic bodies of spindle shape, alternately broad and narrow, in the latter instance having the aspect of coarse fibers of living matter. Thus the uniformity in the structure of the cementum of the neck is established. We hope Dr. Bödecker, with whom we thoroughly concur in all other points, will pardon our heresy and eventually satisfy himself that our conception renders this structure more comprehensible than does his. (See Fig. 72.)

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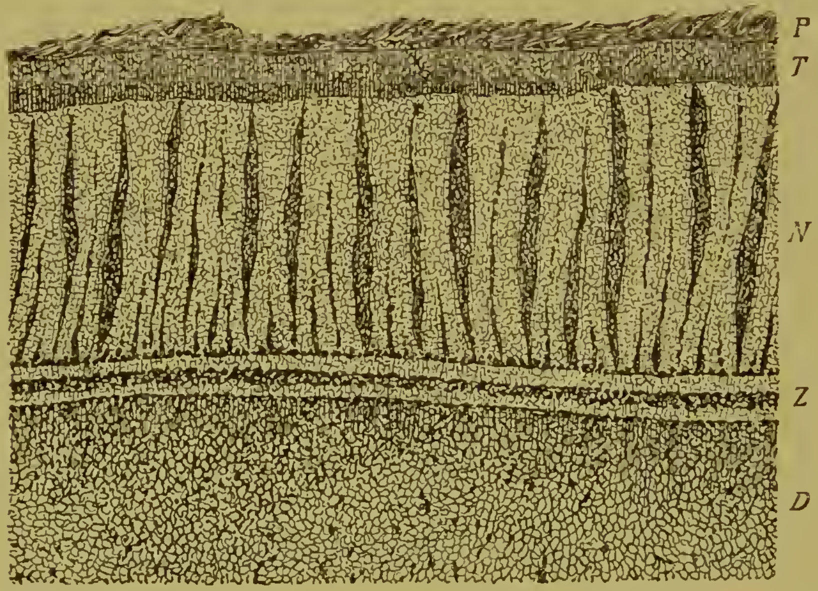
* "A Manual of Dental Anatomy." Philadelphia, 1876.

"Considerable interest attaches to the layer of dentine directly subjacent to the prismatic layer of the cementum of the neck. We are indebted to John Tomes for the knowledge of the fact that the dentinal fibers, in this situation, stop short of the cementum. We may say that nowhere does the structure of the teeth vary in aspect so greatly as in the dentine in the region of the neck. There are scarcely two teeth perfectly alike in this region. The simplest form is when the prismatic layer is directly followed by a granular layer of dentine, lacking canaliculi. That the granulation means a rich reticulum of living matter, coarser than in any other part of the dentine, and rendering the neck excessively sensitive, John I. Hart has proven, fully in accordance with Bödecker's statements. This simple arrangement, however, is rare. In many instances there are layers of stratifications between the cementum and the granular dentine, greatly varying in breadth and in numbers. The appearance of strata, in accord with the conception of John I. Hart, means that alternate layers, rich in living matter, and others scantily supplied with it, build up the neck-region of the

FIG. 72.

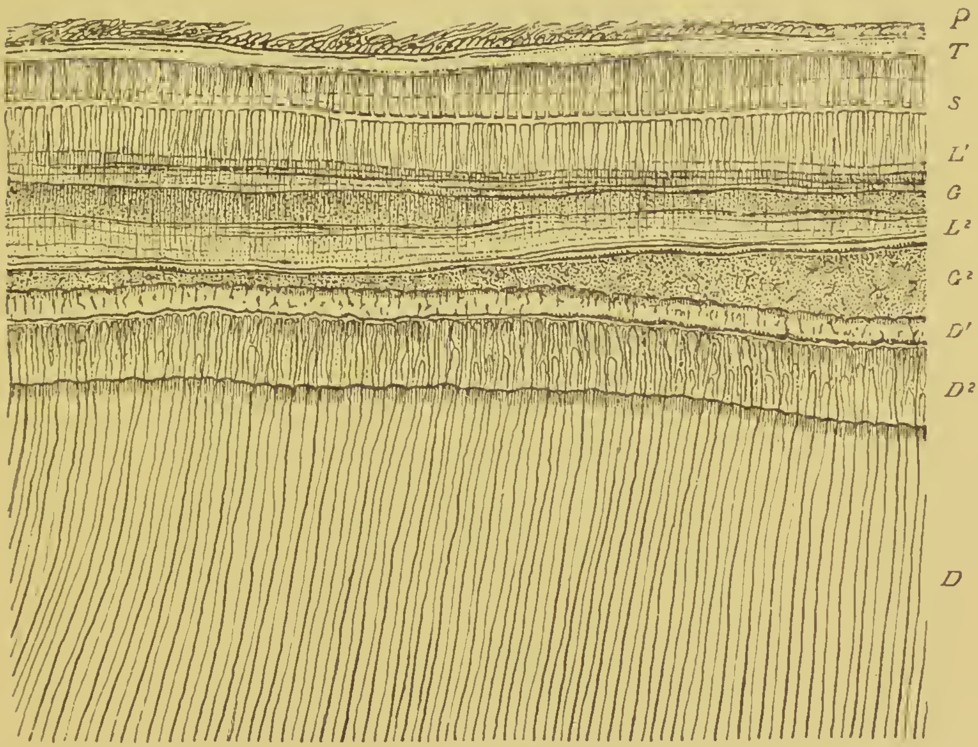


NECK OF A BICUSPID IN LONGITUDINAL SECTION. STAINED WITH CHLORIDE OF GOLD.

P, pericementum; *T*, thickness of the specimen; *N*, cementum of the neck, composed of prisms and intervening spindles and fibers; *Z*, stratified interzonal layer; *D*, coarsely reticulated layer of dentine, destitute of dentinal fibers. Magnified 1200 diameters.

dentine. Club-like or pear-shaped spaces, filled with protoplasm, are often seen to pervade the granular layer of the dentine with a peculiar regularity, and often in connection with dentinal fibers, which otherwise do not reach the boundary of the cementum. In Fig. 72 we find represented in the granular layer of the dentine coarse, dark-violet dots, forming points of intersection, and far too small to be termed protoplasmic bodies or cells in the sense of older histologists. All these features seem to mean a markedly augmented amount of living matter, which renders all surgical interference in the region of the neck so painful.

FIG. 73.



NECK OF A GROUND BICUSPID. ANOMALOUS ARRANGEMENT OF LAYERS OF THE CEMENTUM AND THE DENTINE.

P, pericementum; *T*, thickness of the specimen; *S*, stratified layer of cementum, composed of halved prisms: L^1, outer lamellated layer; *G*, outer granular layer; L^2, inner lamellated layer; G^2, inner granular layer; D^1, thoroughly calcified glossy layer; D^2, inner prismatic layer; *D*, normal dentine. Magnified 200 diameters.

"The most complicated structure that we have ever seen in the region of the neck is illustrated in Fig. 73.

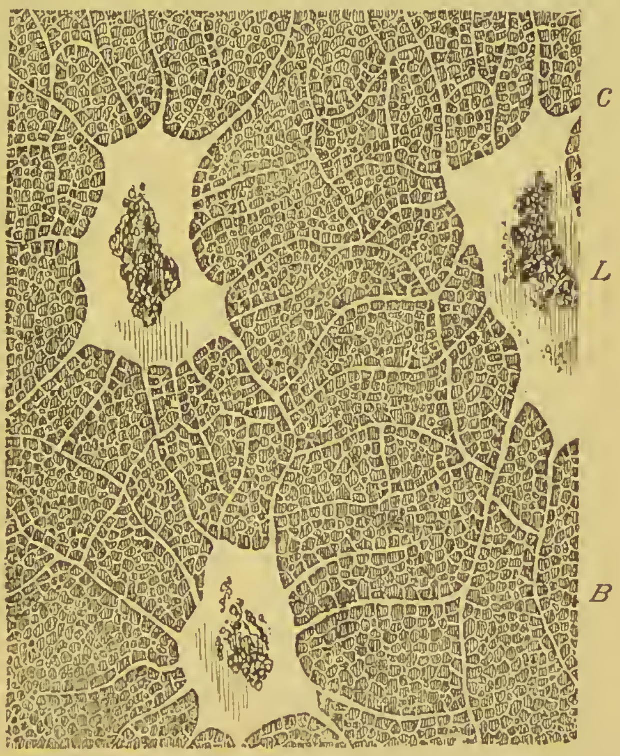
"The figure is taken from a ground bicuspid, which shows at its crown a distinct mechanical abrasion. The stratifications extend all over the root. It is impossible to bring them into a relation with the mechanical abrasion, and we should consider this formation a rather anomalous one. The layers are as follows: The outermost portion, directly bordering the cementum, is composed of large, regular prisms, which show faint longitudinal lines and are halved by distinct fissures in a direction parallel to the surface; this layer extends to the close vicinity of the enamel, and far down along the root, directly changing into stratified cementum, devoid of cement-corpuscles, so far as the specimen shows. This is the only layer that belongs to the cementum, since in the neighborhood of the enamel the dentinal fibers are traceable up to the prisms, pervading a granular basis-substance as yet but slightly stratified. Soon afterward the dentine begins to exhibit a number of layers, which may be defined as composing a narrow outer, and a broad inner, lamellated stratum, between which strata lies the 'outer granular' zone, somewhat varying in breadth along the root. These three strata are pierced by extremely delicate radiating lines, which closely resemble dentinal fibers. The next layer to form is the 'inner granular,' greatly changing in breadth in different portions of the root. This layer holds small, angular protoplasmic formations, and, obviously, corresponds to the granular layer subjacent to the cementum of the neck in normal teeth. Inwardly there follows a zone (D^1) marked by a high gloss due to an intense calcification of the basis-substance, pierced by scanty angular protoplasmic bodies. The innermost stratum appears to be composed of prisms or spindles, far less regular than those of the cementum. A sharp line of demarcation, in which not the slightest anomaly can be made out, closes this layer at its approach to the normal dentine. All these layers are seen down to nearly half the length of the root, where the specimen is cut off.

"Exceptionally there is observable in the dentine of the roots stratification, consisting of narrow, light lines, arranged nearly parallel to the surface, causing an interruption in the course of the dentinal fibers, but never a change in their direction. Stratification of the dentine at the neck is far more common, but has never been seen as yet in such perfection as in the specimen illustrated in Fig. 73. What the cause of such stratification is, future studies in the history of development of the dentine of the roots and the cementum will elucidate.

"**Devitalized Cementum.**—We have ground a number of teeth which, to judge from their naked-eye appearance, were pulpless and devitalized. After the exposure of thin slabs obtained from such teeth to the solution of chloride of gold, with subsequent decalcification with acetic acid, the image under the microscope was striking. (See Fig. 74.)

"The most conspicuous features were the empty lacunæ, destitute of nucleated protoplasm, but containing granular clusters of a dark-violet color, obviously the shriveled remains of protoplasm. Numerous canaliculi arose from the lacunæ, all of which were empty. The finest offshoots of both the lacunæ and canaliculi produced a light net-work in the dark-violet basis-substance,—an image which corresponds to dry and also to necrotic bone. Unfortunately, some specimens of living, freshly-extracted teeth furnished, after the same chemical treatment, identically similar figures. Such an untoward result has also

Fig. 74.



Cementum of the Root of a Devitalized Molar. Stained with Chloride of Gold.

L, lacuna, holding shriveled protoplasm; *C*, empty canaliculi; *B*, basis-substance, pierced by a light reticulum. Magnified 1200 diameters.

occurred to other investigators who resorted to the gold method. The cause of such failure may have been that the extracted teeth were left too long under the influence of the table-salt solution; or, possibly, the acetic acid worked in a wrong way. All we can say is, that whenever such a negative result was obtained, the whole cementum had been affected, so much so that we are at a loss to state whether or not the devitalized cementum is dead all through, up to the pericementum. Future examinations, carried out with improved methods, will probably settle the question where the boundary between dead and living tissue is, this being a matter of the greatest importance to the practitioner."

CHAPTER XIII.

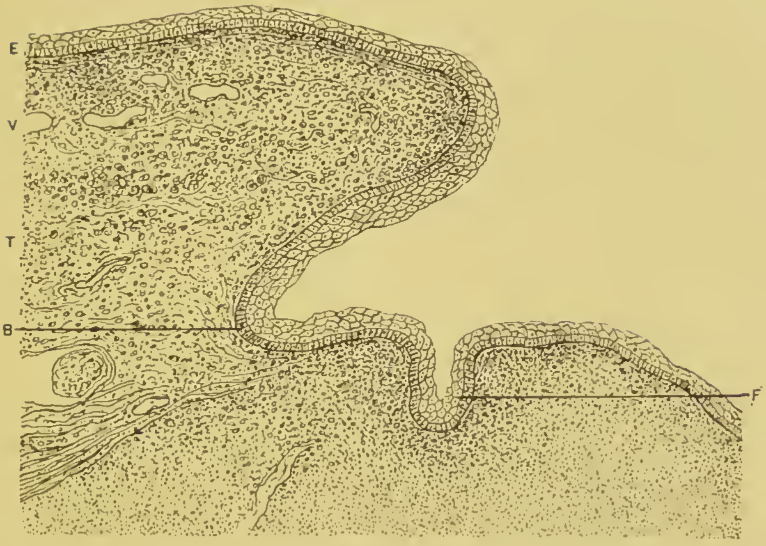
SYNOPSIS OF THE DEVELOPMENT OF THE TEETH.

From a morphological point of view, we might, as several writers have done, consider the teeth to be dermal structures. Their analogy to the skin is, indeed, striking, if we compare the crown of a tooth with a papilla of the skin, especially when the former is in a state of formation,—viz, about the fifth month of intra-uterine development. Here we observe a knob-like formation of connective tissue, the dental papilla, similar to a skin-papilla, supplied with blood-vessels and covered by an epithelial tissue, the *enamel-organ.*

The teeth, during their early stage of development, are composed of only two tissues,—*i.e.*, the enamel and the dentine, the cementum of the root being developed after birth.

The first process in the formation of teeth in the human subject is the evolution of a furrow extending the whole length of the future alveolar process. This furrow appears at about the sixth week of intra-uterine life. (See Fig. 75.) Shortly afterward we observe along the furrow a row of hillocks in the oral epithelium, growing down into the substance of the future jaw. This hillocked epithelial formation is called an enamel-cord, and as development proceeds, the enamel-cord is formed which becomes the enamel-organ of each tooth. About the third month this epithelial cord widens at its distal extremity, which assumes the shape of a bell-jar at the end of the cord. The for-

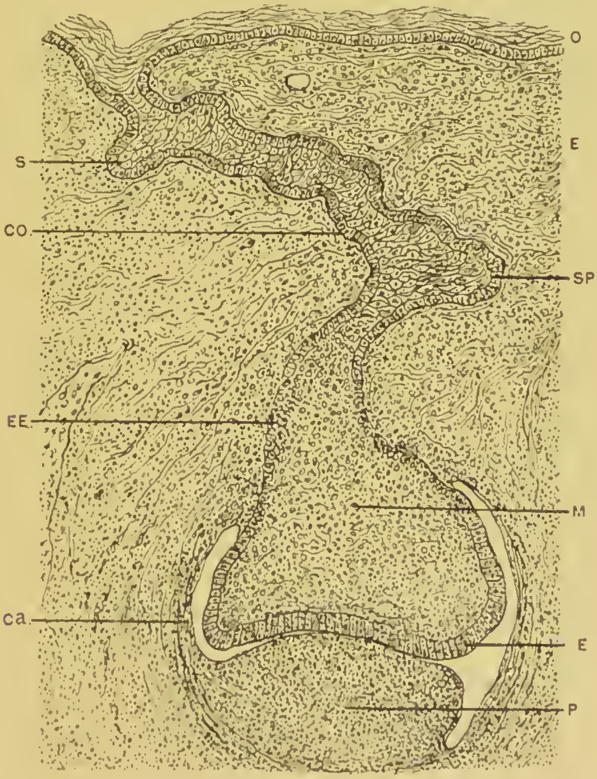
FIG. 75.



TRANSVERSE SECTION OF FURROW ON LOWER JAW OF A HUMAN EMBRYO SIX WEEKS OLD.

E, epithelium of oral mucosa; *T*, tongue; *V*, blood-vessels; *B*, base of oral cavity; *F*, furrow in transverse section. Magnified 75 diameters.

FIG. 76.



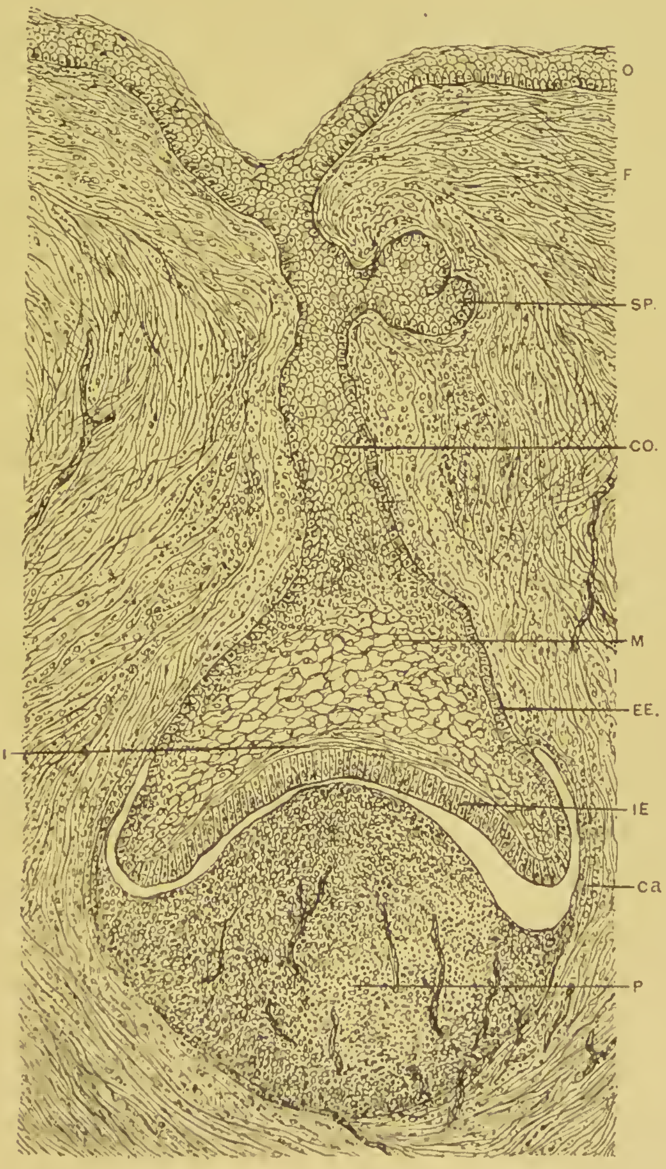
EPITHELIAL CORD TERMINATING IN THE FUTURE ENAMEL-ORGAN OF A HUMAN EMBRYO THREE MONTHS OLD.

O, stratified epithelium of the oral cavity; *Co*, epithelial cord of the enamel-organ; *S*, short secondary offshoot of the epithelial cord; *SP*, broad secondary offshoot of the epithelial cord; *EE*, external or outer epithelium; *E* (lower), internal or inner epithelium; *M*, medullary tissue sprung from previous epithelia, the future stellate reticulum; *P*, dentine-papilla; *Ca*, capsule or tooth-sac; *E* (upper), embryonal tissue, the future fibrous connective tissue of the mucous membrane. Magnified 75 diameters.

mation throughout is composed of two distinct layers of columnar epithelia, continuous with the oral mucous membrane. (See Fig. 76.) At the period in which the bell-shape begins, we see the first trace of the dentinal papilla. About the end of the third month of intra-uterine development we observe that the enamel-organ has changed considerably in shape and size, and we now distinguish the following formations: 1, *the epithelial cord;* 2, *the external epithelium;* 3, *the internal epithelium;* 4, *the stratum intermedium; and* 5, *the stellate reticulum.* (See Fig. 77.) We also notice the beginning formation of the tooth-sac, which grows upward from the dentine papilla, gradually encircling the enamel-organ. About the fifth month the external epithelium of the enamel-organ, together with the epithelial cord, begin to break into epithelial nests and buds, amid which a profuse formation of red blood-corpuscles and blood-vessels takes place. At this period the internal epithelium covering the crown of the future tooth undergoes a change consisting in a prolongation of the single epithelia, and their sum-total is now called the *ameloblast layer*, while those elongated formations covering the dentine papilla are termed *odontoblasts.* The ameloblasts and odontoblasts have been originally in close contact, but with progressing development the dentine begins to form from the periphery toward the center of the tooth; the enamel, on the contrary, grows from the surface of the dentine outward. These changes appear in about the fifth month, wherein also the first trace of dentine is seen, while the enamel begins to form at about the sixth month. Before calcification takes place, there becomes visible on the outermost portion of the ameloblasts a delicate light zone, consisting of embryonal or medullary corpuscles, from which the enamel originates. The odontoblasts at the periphery of the dentine papilla likewise undergo a transformation into medullary corpuscles, and by their calcification give rise to the basis-substance of the dentine. The odontoblasts, as well as the medullary corpuscles sprung from them, are interconnected by delicate threads of living matter. These threads, in coalescence with the offshoots of the odontoblasts, produce the dentinal fibers. The odontoblasts and ameloblasts, therefore, are not directly transformed into the tissues, dentine and enamel, which they respectively represent, but must be considered as provisional formations. During development, the dentine is formed of globular territories, proven by the occurrence of interglobular spaces, and by the retrogressive processes of absorption in temporary teeth, in caries and eburnitis. In this process, the similarity of dentine-tissue with bone-tissue is rendered evident.

The cementum is formed after birth; the remains of the

FIG. 77.



EPITHELIAL CORD TERMINATING IN THE ENAMEL-ORGAN OF A HUMAN EMBRYO FIVE MONTHS OLD.

O, stratified epithelium of the oral cavity; *SP*, secondary offshoot of the epithelial cord; *Co*, epithelial cord of the enamel-organ; *M*, myxomatous tissue of the enamel-organ; *EE*, external or outer epithelium; *IE*, internal or inner epithelium; *I*, stratum intermedium, between inner epithelium and myxomatous tissue; *P*, papilla; *Ca*, capsule or tooth-sac; *F*, fibrous connective tissue of oral mucosa. Magnified 75 diameters.

tooth-sac changing into medullary corpuscles, from which the cementum is developed in the same manner as bone-tissue.

The twenty anterior permanent teeth are developed from enamel-organs, being offshoots from those of the temporary teeth. All the permanent molar teeth are an offspring of the enamel-organ of the second temporary molar teeth.

The writer's views concerning the development of the teeth, as here propounded, differ considerably from those entertained by previous authors. To enable future investigators to satisfy themselves of the correctness of his assertions, the result of eight years of labor, the following is presented as the method resorted to in the pursuit of this study, one of the most fascinating subjects of microscopical research:

To prepare microscopical specimens of embryonal jaws for researches in the history of the development of the teeth, the jaw-bones (preferably the lower) are excised from the fœtus,—care being exercised not to squeeze the specimen,—and are placed in a one-fifth of one per cent. solution of chromic acid. The liquid must be changed every third or fourth day, and the strength of the chromic-acid solution gradually increased to one-half of one per cent., until the hard tissues, by the removal of the lime-salts, are sufficiently soft to be cut with a razor. All trials to determine the degree of softness of such a specimen must be made by means of a needle, and not with the fingers. The epithelial structures are especially liable to be crushed, unless handled with the utmost care. The greatest obstacle to obtaining perfect specimens is caused by the fact that the enamel-organ is withdrawn from the dentinal cap, and the epithelia are detached from the connective-tissue structures, a cavity being thus formed whose walls offer no resistance to the cutting-instruments, and are thus easily detached from their normal position.

After having tried different methods of imbedding, the author has come to the conclusion that the best material for this purpose is celloidin, softened in absolute alcohol and dissolved in sulphuric ether. The specimen, previous to imbedding, must be dehydrated by immersion in absolute alcohol for twenty-four hours. It is next kept in a mixture of equal parts of sulphuric ether and absolute alcohol about twenty-four hours longer. Then it is held in a rather thin solution of celloidin for about two days, after which it is ready for mounting upon a cork. When such a specimen is cut, it will usually be found that the spaces between the dentine and enamel, which are due to the shrinkage of the myxomatous tissue of the enamel-organ, are filled with celloidin. If, however, it is found, upon cutting, that such a space has not been completely filled, a very thin solution of celloidin may be poured into it. A section-cutter is of great advantage, since by its use a large number of thin and uniform specimens can be obtained in a comparatively short space of time.

Chemically-pure glycerin is considered far superior to Canada balsam as a mounting medium, the tissues of the object presenting in this medium a more distinct appearance. If high powers of the microscope are to be employed, only glycerin-mounted specimens will give satisfactory results.

CHAPTER XIV.

DEVELOPMENT OF DENTINE.*

Dentine, as is universally admitted, is strictly an offspring of connective tissue produced by the papilla, a formation of embryonal tissue, crowded with medullary corpuscles. (See Fig. 78.)

It appears about the end of the second and the beginning of the third month of intra-uterine life, at a time when the extremity of the epithelial cord has flattened and assumed a cup-shape. The cavity of this cup is filled with the papilla, which sends prolongations along the outer wall of the cup, the future sac of the tooth. The more this is deepened and widened, the larger will be the papilla. If the cup of the enamel-organ shows depressions corresponding to a bicuspid or molar tooth, we shall find corresponding elevations upon the papilla extending into them.

The papilla is originally supplied with but few capillary blood-vessels. With advancing growth, however, the vascular supply becomes greater, especially in its peripheral portions, where a delicate fibrous connective tissue is developed,—the so-called tooth-sac. In the seventh month of fœtal life, we observe a perfect vascular apparatus traversing the papilla, consisting of arteries, veins, and capillaries. If examined with low powers of the microscope, the papilla appears to be composed of small, globular, highly-refracting corpuscles, amid which is seen a scanty basis-substance. With high powers of the microscope, we observe globular or oblong corpuscles of small size, which are either compact and homogeneous, or possessed of a distinct reticular structure in their interior. Between small groups of such medullary corpuscles, spindle-shaped tracts appear, corresponding to the boundaries of the future territories of the myxomatous tissue, the reticulum of which in the human subject is always incomplete, never attaining the degree of development seen in the enamel-organ. The largest medullary corpuscles are observed in the middle of territories surrounded by a certain amount of basis-substance. Both these corpuscles and the basis-substance have a distinct reticular structure. (See Fig. 78.)

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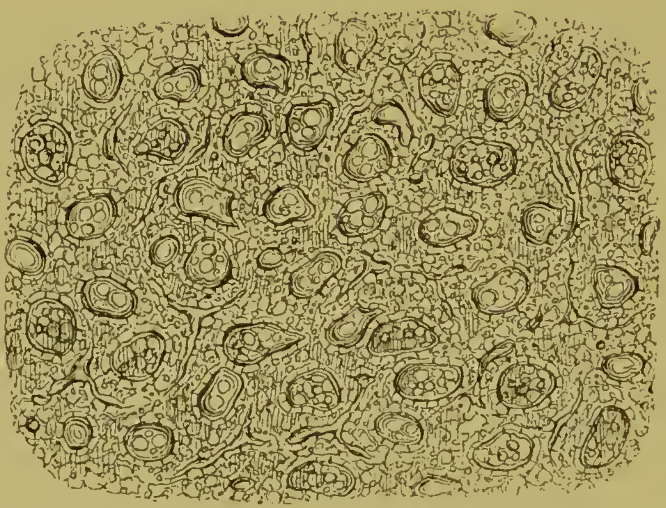
* "Contributions to the History of Development of the Teeth." By C. Heitzmann and C. F. W. Bödecker. *The Independent Practitioner*, vols. viii and ix.

Fig. 78.



Medullary Tissue of the Papilla of a Human Embryo of Four Months.

The small shining medullary corpuscles form clusters, around which we observe an irregularly developed myxomatous net-work. Magnified 1200 diameters.

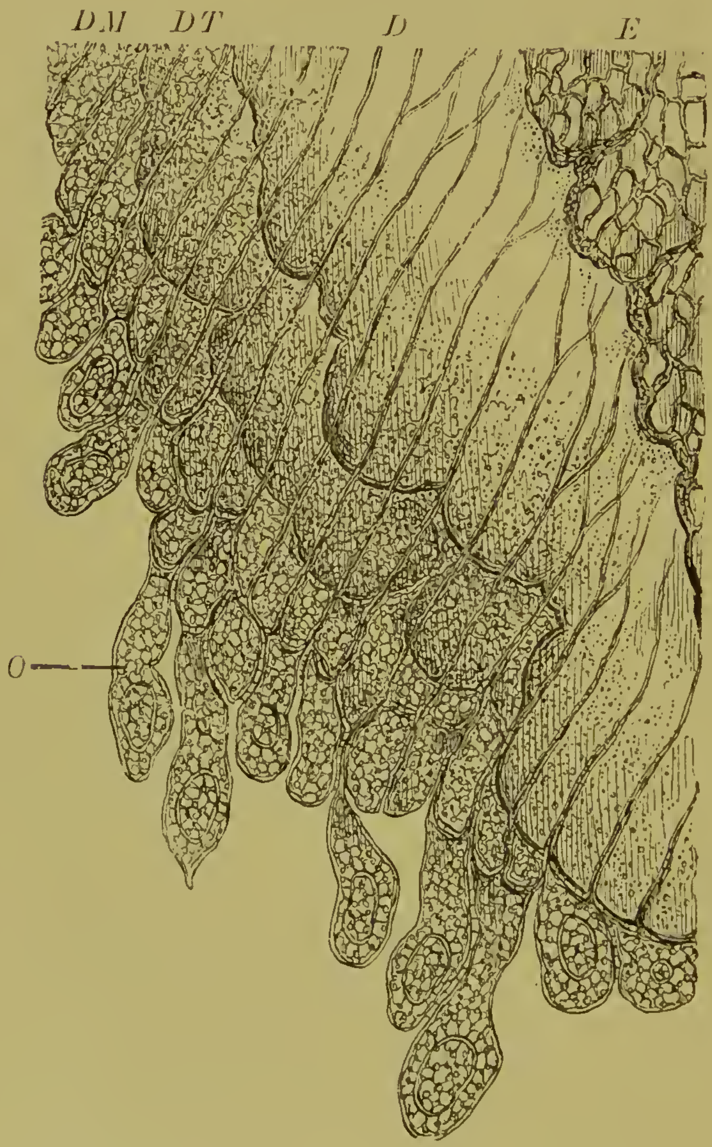
The more the papilla increases in size and advances in development, the less frequent are the homogeneous and small medullary corpuscles, while the granular corpuscles are larger, each being surrounded by a small amount of basis-substance. Along the periphery of the papilla, however, there is invariably present a narrow zone, in which the medullary corpuscles are more numerous and more shining than in the rest of the papilla.

In the fifth month the outermost periphery of the papilla is frequently found to be composed of a hyaline rim, beneath which is a narrow zone of medullary corpuscles. The hyaline rim corresponds to the so-called structureless layer, or basement membrane so often seen between epithelial and connective-tissue formations. When the enamel-organ is detached from the papilla,—and this detachment is, as above said, very frequent,—the outer surface of the basement membrane appears beset with an extremely delicate fringe, evidently the torn connection between the papilla and the adjacent enamel-organ, or the ameloblasts. High powers of the microscope reveal in the apparently structureless layer a faint reticular formation, and marks of a division into medullary corpuscles.

At the beginning of the fifth month, we usually find along the periphery of the papilla the first traces of peculiar, elongated corpuscles, known as odontoblasts. These formations are oblong, pear-, club-, or spindle-shaped, arising from the coalescence of a number of medullary corpuscles, including that portion which has been previously transformed into basis-substance. The odontoblasts are sometimes seen directly beneath an already-formed layer of not yet calcified dentine. The latter, in this case, is sufficiently characterized by the presence of delicate branching dentinal canaliculi, holding the slender dentinal (Tomes) fibers. We often observe these fibers to be in direct connection with adjacent odontoblasts. If an odontoblast terminates in a sharp point, one offshoot directly connected with a dentinal fiber is seen to arise from the point. If an odontoblast has a broad basis, two or more offshoots may arise from it and run, in the shape of dentinal fibers, into the adjacent dentinal canaliculi. It may also happen that an offshoot of an odontoblast takes another direction, and instead of passing into a dentinal canaliculus, runs parallel with the border of the already-formed dentine. Fully-developed odontoblasts are not often seen in direct union with dentine, and this is especially true along the lateral portions of the dentinal cap. It is far more common that medullary corpuscles are present between the odontoblasts and the dentine, and that the offshoots of the odontoblasts run between these medullary corpuscles in order to reach their respective dentinal canaliculi. Fully-developed odontoblasts are rarely seen at the apex of the papilla. Usually medullary corpuscles only are present in this locality, or they are interposed between the odontoblasts and dentine. Not infrequently we observe in the forming dentine layers as are represented in Fig. 79.

The odontoblasts have arisen from the fusion of a number of

FIG. 79.



FIRST-FORMED DENTINE OF A HUMAN FŒTUS OF SIX MONTHS.

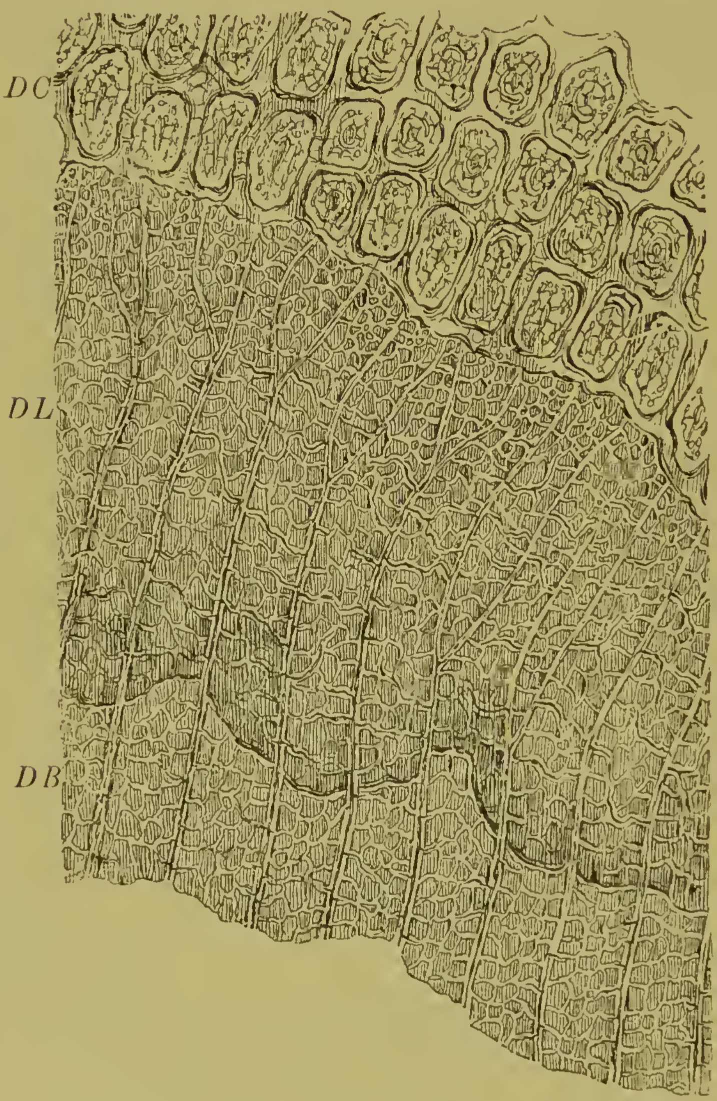
D, calcified layer of dentine with marked globular territories; *DT*, dentine composed of a non-calcified basis-substance, likewise globular; *DM*, row of medullary corpuscles before the formation of basis-substance; *O*, odontoblasts, the offshoots of which run between the medullary corpuscles into the dentinal canaliculi; *E*, enamel. Magnified 1200 diameters.

medullary corpuscles, and are present where, at the time, the formation of dentine is not actively in progress. Whenever this is the case, the odontoblasts break up into medullary corpuscles, which are directly transformed into the basis-substance of the dentine. The offshoots of the odontoblasts, that are seen to run directly into the dentinal canaliculi, appear between the medullary corpuscles as soon as the odontoblasts split up into such corpuscles. The offshoots are formations of living matter seen to emanate from a compact layer at the base and the borders of the odontoblasts. The dentinal fibers remain in situation after the formation of medullary corpuscles, or they are newly formed between the medullary corpuscles, as soon as the dentinal canaliculi are formed. The odontoblasts are not direct dentine-formers, but provisional formations, from which arise the medullary corpuscles, and these are changed into the basis-substance of the dentine. Odontoblasts, therefore, the same as ameloblasts, are provisional formations, and dentine, as well as enamel, originates from medullary corpuscles in the same manner in which all forms of connective tissue are known to arise.

It is the rule that the medullary corpuscles are at first transformed into a basis-substance, which is as yet destitute of lime-salts. In specimens stained with carmin, this zone of non-calcified dentine assumes a bright red color, in contradistinction to the calcified portion, which either remains unstained or assumes a greenish tint by the reduction of the chromic acid. Another distinction between the non-calcified and the calcified basis-substance is that the latter has a markedly higher degree of refraction than the former. When we examine such a specimen with high powers of the microscope, we at once become convinced of the identity of the structure of both the non-calcified and the calcified dentine. We observe a markedly reticular structure in both, and in many instances fine filaments, emanating from the dentinal fibers, are seen to penetrate the reticulum.

At the periphery of the dentine, the bifurcations of the dentinal canaliculi and their tenants are always plainly marked. This feature obviously arises from an aggregration of smaller medullary corpuscles than those appearing at a later period of development. At the same time, the reticulum in the basis-substance is more delicate in the region of the bifurcations, and consequently the meshes of the basis-substance appear narrower in the first-formed dentine than in that which is formed at a later period. We sometimes observe, in connection with longitudinal sections of dentine, transverse sections which are of great interest. (See Fig. 80, *DC*.) Here it is seen that the calcification first starts at the periphery of the fields farthest from the dentinal canaliculi. Thus a comparatively coarse network of calcified basis-substance is established, in the meshes of which we observe either an uncalcified basis-substance or unchanged protoplasm, whereas the central portions of the meshes are occupied by the dentinal fibers in transverse or oblique section. The latter appear larger in inverse ratio to the amount of calcareous matter that has been deposited. From their periphery arise the spokes, also seen in fully-devel-

FIG. 80.



FIRST-FORMED DENTINE OF THE MOLAR TOOTH OF A HUMAN FŒTUS OF SIX MONTHS.

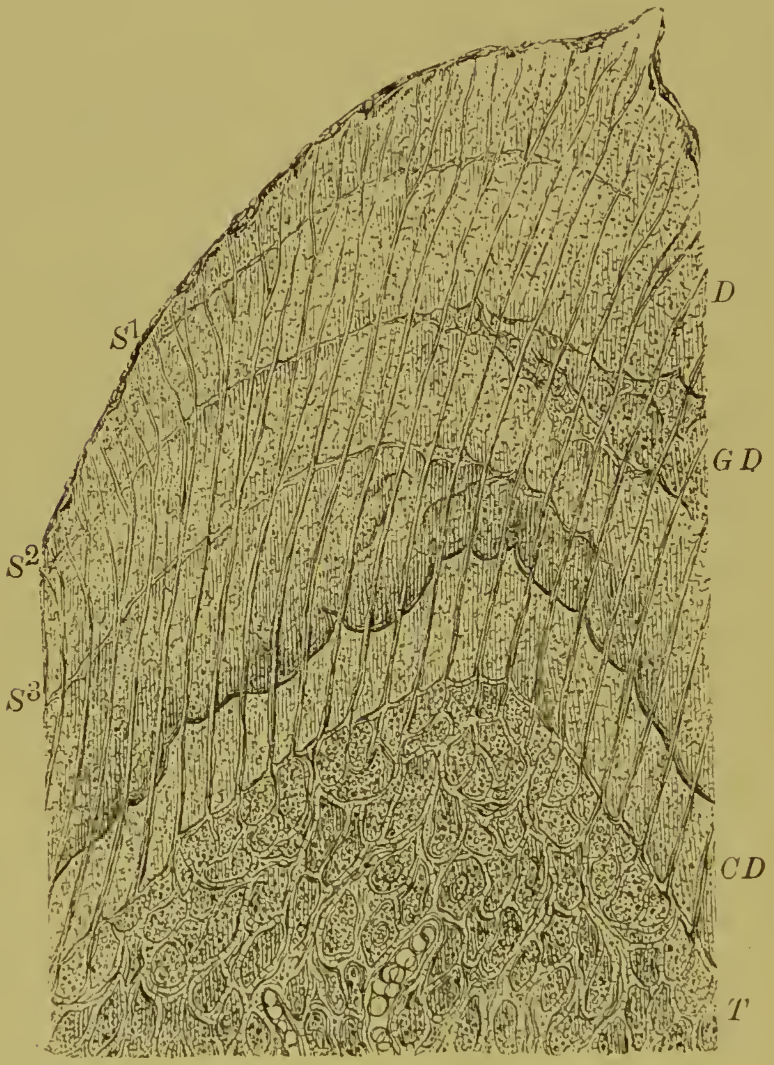
DB, basis-substance of non-calcified dentine; *DL*, basis-substance of calcified dentine, both in longitudinal section; *DC*, calcified dentine in cross-section. Magnified 1200 diameters.

oped dentine, which traverse a light rim—the future canaliculus. The border of the canaliculus is often marked by a circular or crescentic formation, possibly the future rim of elastic substance of the dentinal canaliculi.

The line of the non-calcified basis-substance forming the boundary toward the medullary corpuscles is found to be either straight, stair-like, or slightly wavy. This feature is never observed close to the periphery of the dentine, but always some distance away from it. These wavy contours unquestionably correspond to the globular territories of which the basis-substance is composed. Previous researches regarding dissolution of the dentine of temporary teeth, in caries and in the process of eburnitis, especially in the latter, have strongly pointed toward the presence of globular territories in the dentine, the same as in bone-tissue. The history of development corroborates the presence of such territories, since they are of very common occurrence in developing dentine of man, as well as of different animals. Their origin is explained in a grouping together of a certain number of medullary corpuscles previous to their transformation into basis-substance. Each globular territory is pierced by a number of dentinal canaliculi, without the least interruption in their course. We desire to lay special stress upon the fact that such territories become conspicuous only after calcification of the basis-substance has taken place. Under the theory that the odontoblasts are directly transformed into dentine, the formation of globular territories was inexplicable. In morbid processes, we observe the globular territories of the dentine breaking up into a number of medullary corpuscles. The history of development teaches us that each territory arises from a number of smaller corpuscles. Thus the formation, dissolution, inflammation, and reformation of dentine become plain.

Since Czermak has drawn attention to uncalcified fields in the dentine of many teeth, and called them "interglobular spaces," a great deal of speculation has been indulged in to explain this occurrence. Such spaces are never present, as far as the writers have observed, close to the periphery of the dentine, but are always found some distance from the bifurcations of the dentinal canaliculi, and sometimes are scattered throughout the dentine. These spaces are filled with a non-calcified basis-substance, or with medullary corpuscles that have not been transformed into basis-substance. We have often observed within these spaces irregular globular territories, invariably marked by the contours of such territories, but never causing a deviation of the course of the dentinal canaliculi.

Fig. 81.



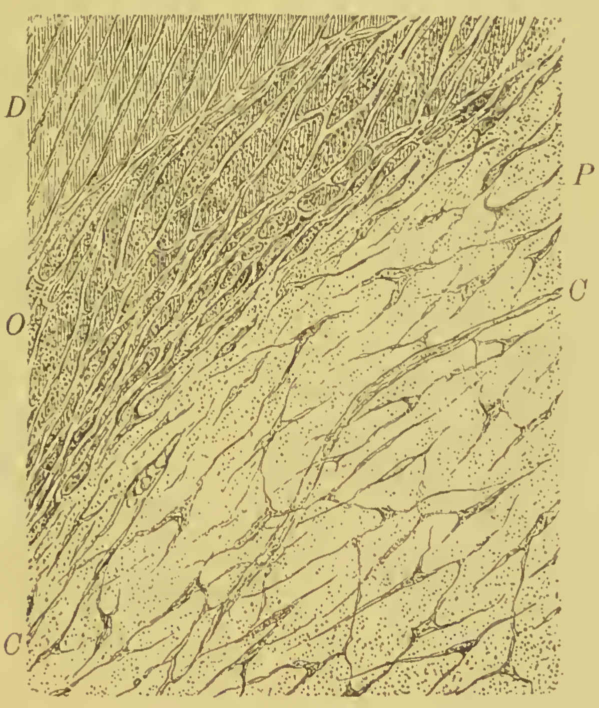
Anomalous Formation of Dentine from a Human Fœtus of Six Months.

T, papilla of the tooth, with a few blood-vessels, and no odontoblasts. The medullary corpuscles, close below the dentine, are arranged in groups, corresponding to the future territories of the dentine; *CD*, non-calcified basis-substance of the dentine; *D*, calcified dentine; *S*, 1, 2, and 3, stratifications of the dentine; *GD*, ill-calcified basis-substance of the dentine, in connection with *S*2, composed of globular territories. Magnified 500 diameters.

The origin of such interglobular spaces is traceable to the earliest stages of the formation of the dentine. (See Fig. 81.) In exceptional cases even fully-developed dentine will appear composed of layers, or with faint concentrically-arranged marks, traversed without interruption by the dentinal canaliculi. Both the stratification and the interglobular spaces are caused by a faulty deposition of lime-salts in the embryonal development of the dentine. Their cause is probably a temporary interruption of deposition of lime-salts, owing to transient ailments of the mother. These rather anomalous formations of dentine again prove that the basis-substance is made up of globular territories, and these, again, of medullary corpuscles.

In the fœtus of the cat, the sheep, and the dog, the process of the formation of dentine is the same as in man, in all essential features. The same rule holds good for the history of the development of dentine in swine. This dentine, in development, differs slightly from that of man, mainly in the structure of the papilla. (Fig. 82.)

Fig. 82.



Papilla and Adjacent Dentine of Fœtus of a Pig.

P, myxomatous tissue of the papilla, with irregularly branching corpuscles, and an abundance of myxomatous basis-substance; *C*, *C*, capillaries, partly fully formed, and partly in the process of formation; *O*, layer of odontoblasts; *D*, dentine. Magnified 500 diameters.

The papilla of the fœtus of a pig is composed of irregular, branching, and partly connecting protoplasmic bodies, somewhat resembling the stellate reticulum of the enamel-organ.

These corpuscles are uniformly distributed in an abundant mass of basis-substance, which, with lower powers of the microscope, appears finely granular. High powers, however, reveal the delicate net-work essential to all the varieties of a myxomatous basis-substance. This tissue is traversed by a moderate number of blood-vessels, mainly capillaries, which show in some places characteristics of the stages of development from the original solid cords of protoplasm to the vacuolization and appearance of endothelia upon their walls. Toward the periphery of the papilla, spindle-shaped bodies make their appearance, evidently arising (at least to a great extent) from the living matter previously hidden in the myxomatous basis-substance. By an increase in the size of one, or the confluence of several, such spindle-shaped corpuscles, the odontoblasts arise, and they are often seen in contact with the already-formed dentine. Close study of specimens has satisfied us that the odontoblasts do not directly form the basis-substance of the dentine, but here, as well as in men and other animals, are merely transitional formations.

Fig. 83.

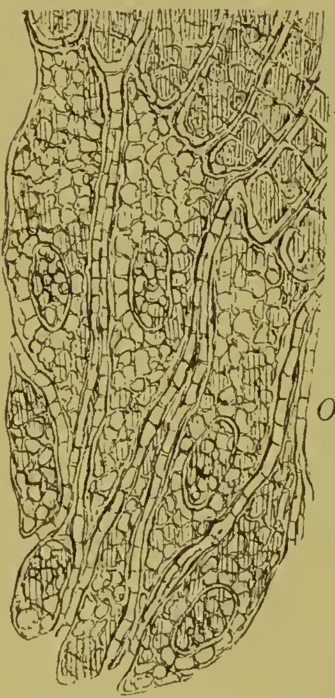
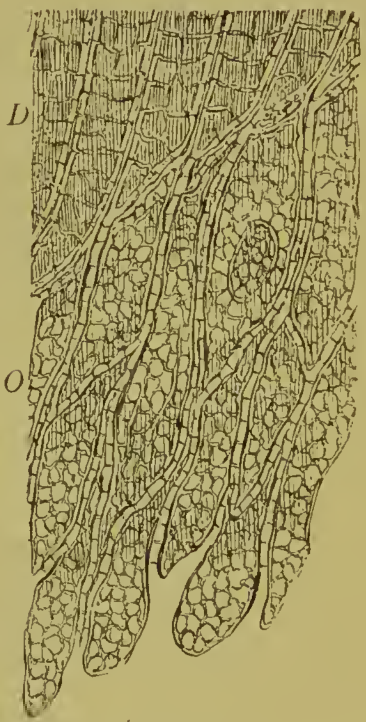


Fig. 84.



Odontoblasts, with Adjacent Dentine, from the Fœtus of a Pig.
O, odontoblasts; *D*, dentine. Magnified 1200 diameters.

In the condition of rest the odontoblasts offer an excellent opportunity to study their relation to the dentine. If they lie against the dentine with a broad basis, four or five offshoots (as represented in Fig. 83) may be seen to enter the adjacent canaliculi, all of which arise from one odontoblast. If, on the contrary, the odontoblasts terminate, toward the dentine, in a point, a single dentinal fiber will spring therefrom, as represented in Fig. 84. It may also happen that a single odontoblast exhibits no offshoots, in which instance we observe, between the base of the odontoblast and the dentine, delicate filaments which run along the border of the dentine, and from which arise the dentinal fibers. The opposite ends of the odontoblasts are, roughly speaking, pointed, and likewise elongated into delicate fibers. These fibers, as well as the lateral portions of the odontoblasts, are interconnected with all their neighbors by means of delicate thorny offshoots.

The results of further researches in this field, as follows, have been published by Frank Abbott: *

"The only formations deserving of the term 'cells' are the odontoblasts, those peculiar, elongated bodies (of a shape and size to remind one of columnar epithelia) usually seen at the periphery of the papilla in developing, and at the periphery of the pulp-tissue in developed teeth.

"We know of these peculiar protoplasmic bodies that they send offshoots (the dentinal fibers) upward into the dentine, offshoots laterally connecting one with another, and other offshoots downward, uniting them with the medullary elements of the papilla.

"The first to see and describe all these offshoots was Franz Boll, in 1868, and he was corroborated by Waldeyer, in 1869. Before these offshoots were known, attempts at explaining the formation of dentine were made, first by A. Kölliker, in 1852, in his hand-book of histology. On page 385 he says, 'In the formation of dentine not the whole pulp is concerned, but only its outermost layer of epithelium-like cells, which, by a continual prolongation of the original cells, *under a continuous multiplication of the nuclei*, apparently keep up the same thickness.

"'I am not willing to maintain that one and the same cell is sufficient for the whole duration of the formation of dentine, for I consider it as quite possible that, from time to time, the dentine-cells are replaced by others forming at their inner side. What I deny is, that the whole pulp is transformed and ossified from without inward.'

---

* "Odontoblasts in their Relation to Developing Dentine." *Dental Cosmos*, 1888.

"Kölliker, at that time, knew nothing about the presence of dentinal fibers. To explain the formation of the dentinal canaliculi, he, on page 386, discusses the following three possibilities:

"1. The canaliculi are the remnants of the cavities of the dentinal cells, which, in the process of ossification, become thickened and hardened in their walls, but are not perfectly closed.

"2. The canaliculi originate from the nuclei of the dentinal cells, which elongate and coalesce, but retain their central cavities.

"3. The canaliculi are produced by a process of resorption in the previously homogeneous dentinal tissue, in a manner analogous to the formation of the Haversian canals, or the canaliculi in the cementum.

"Of these three possibilities, Kölliker considered the first as the most probable for the formation of the main canaliculi, and was convinced that the third possibility alone can explain the origin of the fine-branching canaliculi. He distinctly states that no other tissue is concerned in the production of dentine but the cells which later were dubbed odontoblasts, and that these, by a successive taking up of the lime-salts, become dentine. He therefore, as early as 1852, although upholding until then the secretion theory, adopted, and from that time up to date has unswervingly maintained, as regards the formation of dentine, the opposite or transformation theory. About ten years later, he and John Tomes discovered the dentinal fibers, and, with the acknowledged evidence of these fibers within the canaliculi, and their connection with the odontoblasts, the difficulties in explaining the formation of dentine have considerably increased.

"Are the dentinal fibers remnants of the central portion of the odontoblasts, whose lateral portions become transformed into basis-substance? Are the dentinal fibers formed between the odontoblasts after the latter have become basis-substance? So great, indeed, seemed the puzzle, that quite recently R. R. Andrews deemed it advisable to reiterate a previously-expressed opinion of E. Klein and others, that there are two sets of odontoblasts, some with broad bases which become basis-substance altogether, and others pear- or spindle-shaped, with long projections, which become the dentinal fibers. These latter they termed 'fibril-cells.'

"It would seem to require a very limited amount of histological or microscopical experience to satisfy oneself of the untenableness of these views, as, with not a very high power, projections may be seen running from every odontoblast into the canaliculi of the formed dentine, some giving off one, some two, some three such projections; while even as many as five offshoots have been seen arising from a very broad end of an odontoblast, and penetrating the canaliculi. The 'fibril-cells,' therefore, are nothing but narrow wedges between broad-based odontoblasts, especially numerous where the periphery of the papilla forms a sharp curvature, as on the pointed cusps.

"Several questions, however, require our close attention in the history of the development of dentine. One of these is, Are the odontoblasts absolutely necessary as a stage preliminary to the formation of dentine? And secondly, how is it that the odontoblasts produce a continuous mass of dentine from the periphery to the pulp, if they are converted into basis-substance in layers? For we know that the dentine is only in exceptional cases stratified, whereas one would expect such lines of stratification to be of common occurrence, if one row of odontoblasts after another were to be converted into basis-substance.

"As to the first question, we are unable to give a positive answer, but take it for granted that the response should be affirmative, and that the odontoblasts are a prerequisite to the formation of dentine. We often see, at the summit of the papilla, medullary tissue bordering the already-formed dentine without a trace of odontoblasts. Through the researches of John Tomes, we know that the odontoblasts originate in the coalescence of medullary corpuscles of the papillary tissue; and we know, furthermore, that the odontoblasts again return to the medullary condition before becoming infiltrated with lime-salts. It appears possible that previous odontoblasts have been transformed into medullary tissue, and no new ones produced at that particular period.

"To the second question, whether or not the odontoblasts form a single row for the time being, thus involving an interruption in the appearance of the basis-substance of the dentine, a positive answer can be given, in accord with the observations of Kölliker in 1852, above quoted. The difference, however, between his views and ours is, in our judgment, sufficiently marked to demand attention.

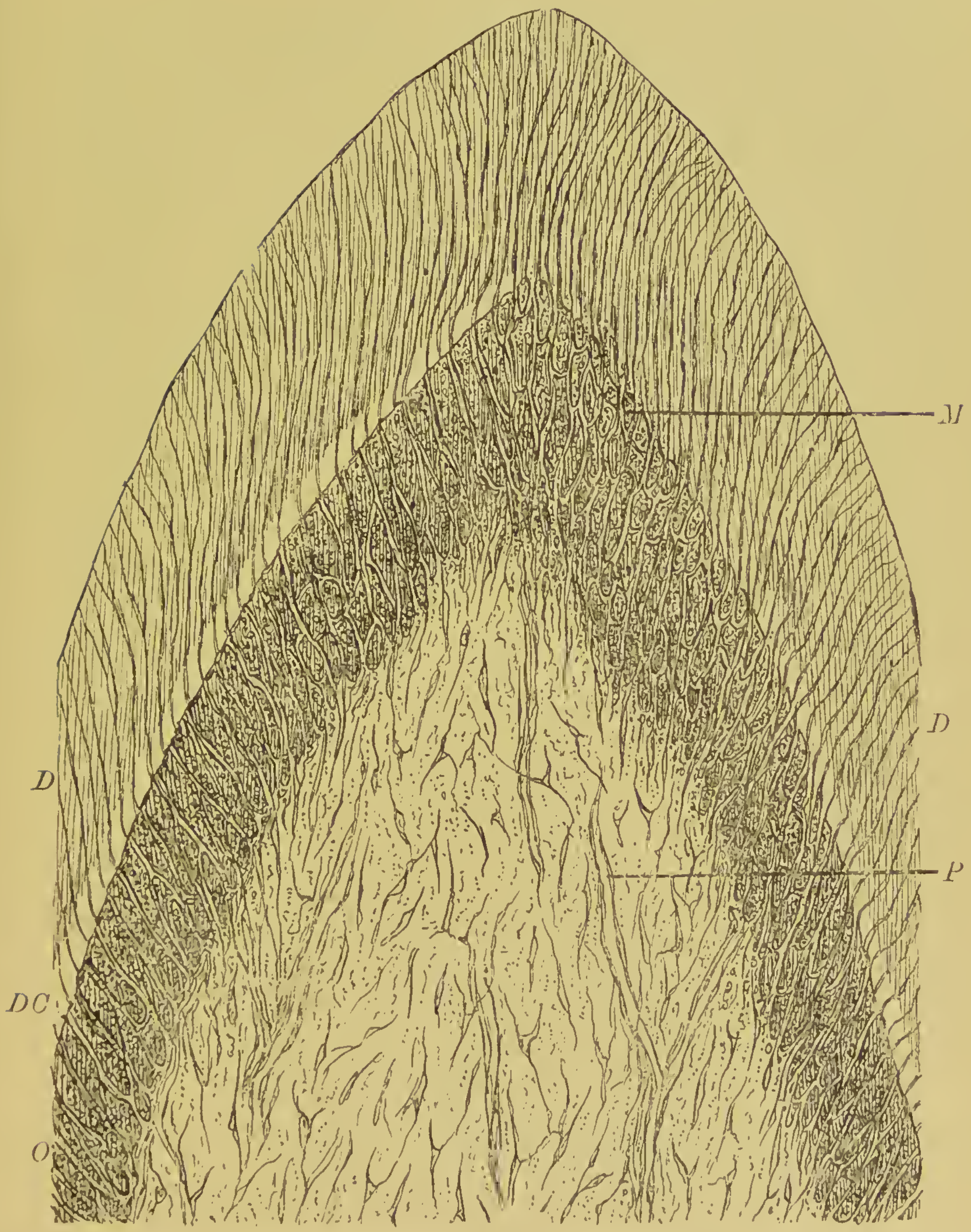
"He declares that there is but one row of odontoblasts capable of producing dentine, and that these become continuous by a proliferation of the nuclei of the original single row. He distinctly denies that the pulp as a whole can be converted, layer after layer, into odontoblasts. We, on the contrary, agree with John Tomes in the view that the medullary corpuscles of the papillary tissue are progressively converted into odontoblasts,—a view which explains the fact that, with the advancing growth of the dentine, the bulk of the papilla diminishes. We add another point,—viz, *that each odontoblast, while being reduced to medullary corpuscles at its distal or peripheral end, is being added to by an attachment of medullary corpuscles of the papillary tissue at its proximal or central end.*

"Undoubtedly there are periods of comparative rest, in which a fully-developed odontoblast borders the dentine, and dips into the papillary tissue with sharply-defined contours, with its narrow and pointed end. As soon, however, as the building of dentine is resumed, the peripheral end of the odontoblast is seen to have divided itself into medullary bodies again, and, simultaneously, rows of medullary corpuscles are superadded to the opposite or central end.

"A beautiful illustration of this process may be seen in the developing tooth of a pig's fœtus, ten centimeters long. (See Fig. 85.) Here we see several rows of odontoblasts, bordering the non-calcified portion of the basis-substance of the dentine. At that portion, in which unchanged odontoblasts stand against the dentine, others are attached to the uppermost row, likewise in full development. This we consider as a condition of comparative rest. At that portion, on the contrary, in which the odontoblasts are replaced by medullary corpuscles toward the dentine, without a distinct boundary-line between the two, we see rows of medullary corpuscles attached to the inner ends of the odontoblasts, whereby the transverse diameter of the odontoblastic layer is noticeably broadened. In the former instance, the layer of odontoblasts is fairly well marked toward the papillary tissue; in the latter instance it is indistinct, the odontoblasts blending with the papillary tissue.

"High powers of the microscope still better illustrate this view. (See Fig. 86.) At the same time it becomes evident that the dentinal fibers, originally attached to and connected with the odontoblasts, become situated between the medullary corpuscles

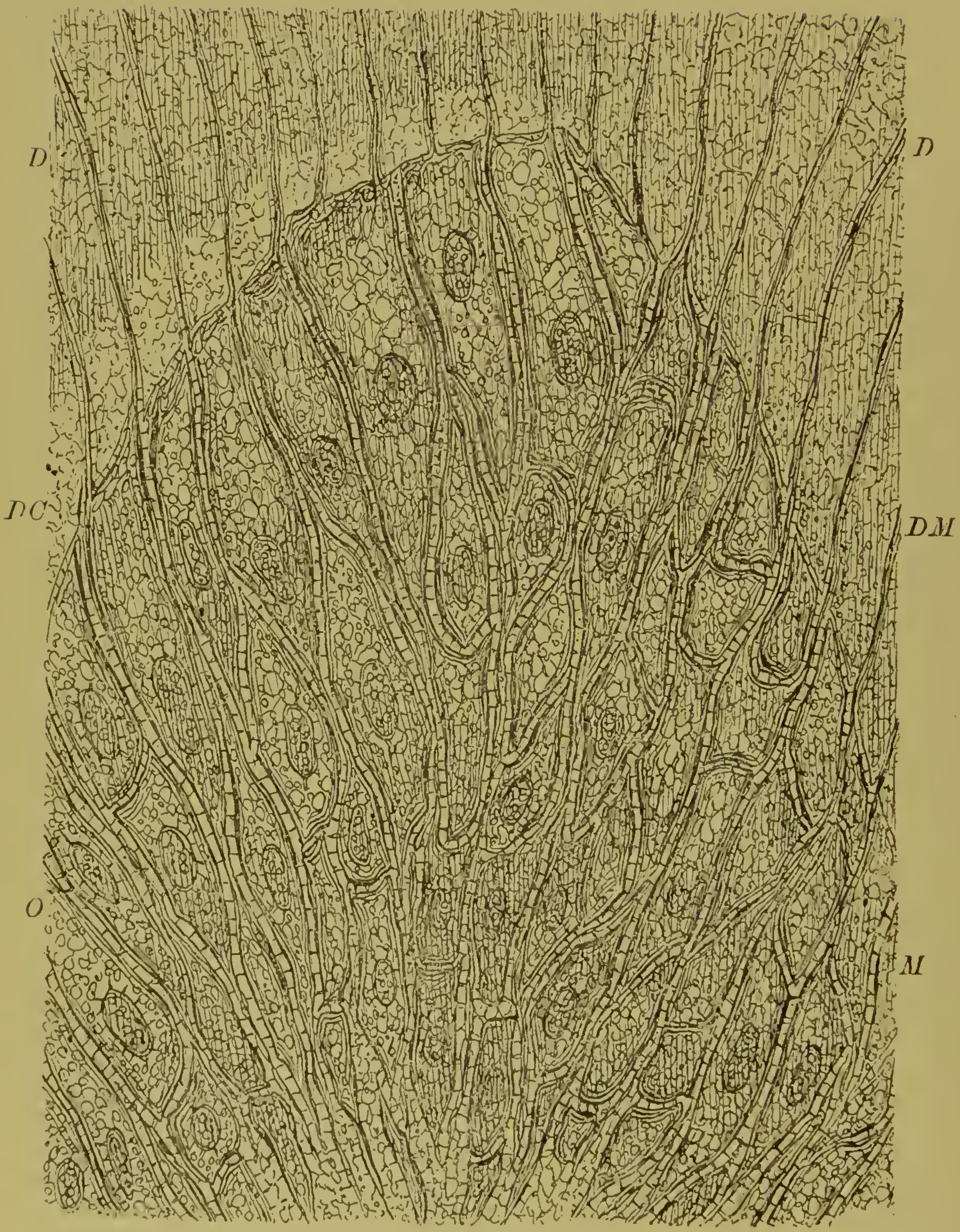
FIG. 85.



TOOTH OF A PIG'S FŒTUS 10 CENTIMETERS LONG.

D, D, calcified dentine; *DC*, non-calcified dentine; *O*, row of odontoblasts, partly fully formed, partly forming; *M*, odontoblasts broken up into medullary corpuscles in the process of formation of dentine; *P*, vascularized myxomatous tissue of papilla. Magnified 400 diameters.

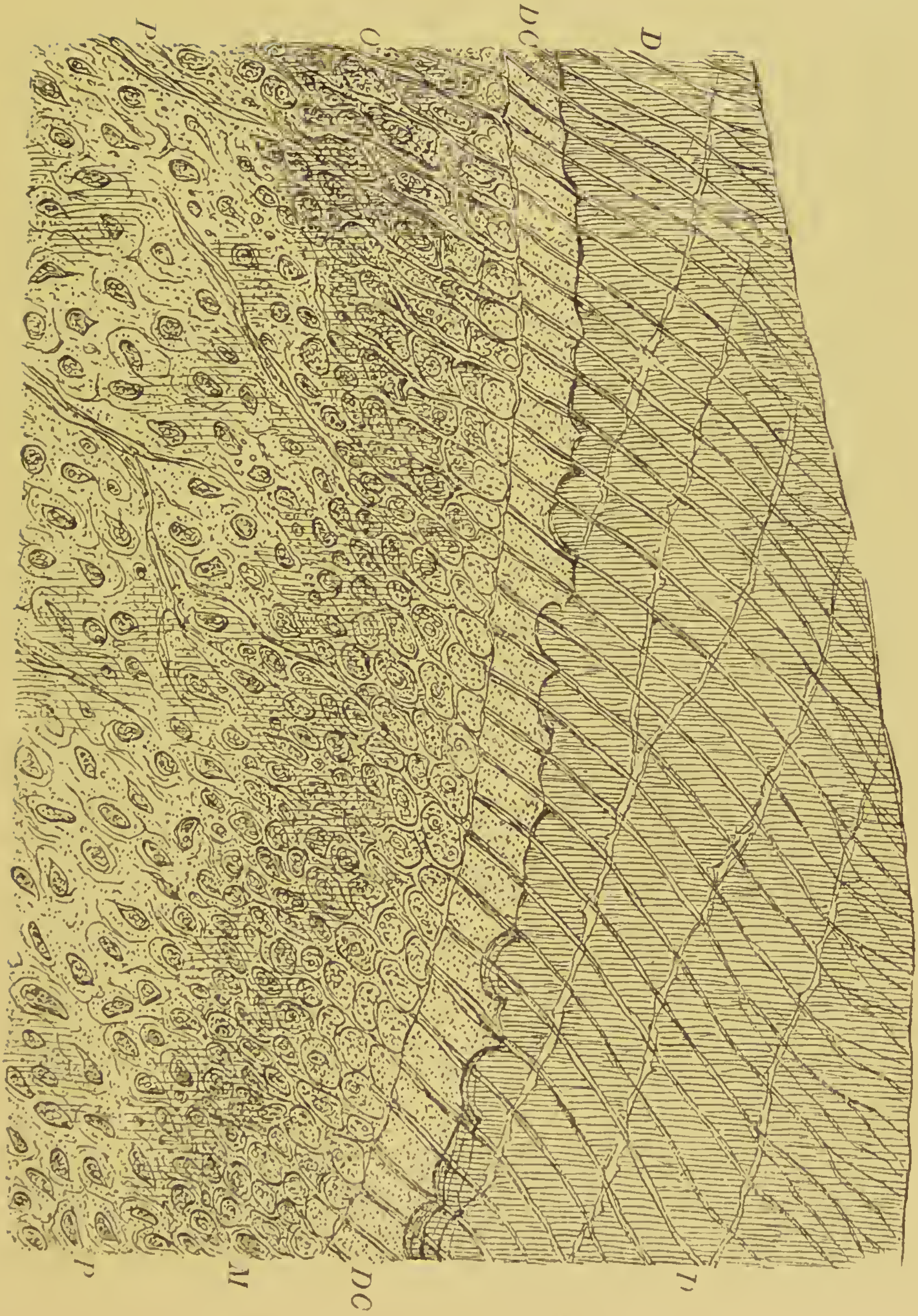
Fig. 86.



Tooth of a Pig's Fœtus 10 Centimeters Long.

D, *D*, calcified dentine; *DC*, non-calcified dentine; *DM*, dentine in the process of formation from medullary corpuscles; *O*, odontoblasts in multiple rows, spindle-shaped elements wedged in between the broad odontoblasts; *M*, medullary corpuscles arisen from odontoblasts, such corpuscles also attached to the distal ends of the odontoblasts. Magnified 1200 diameters.

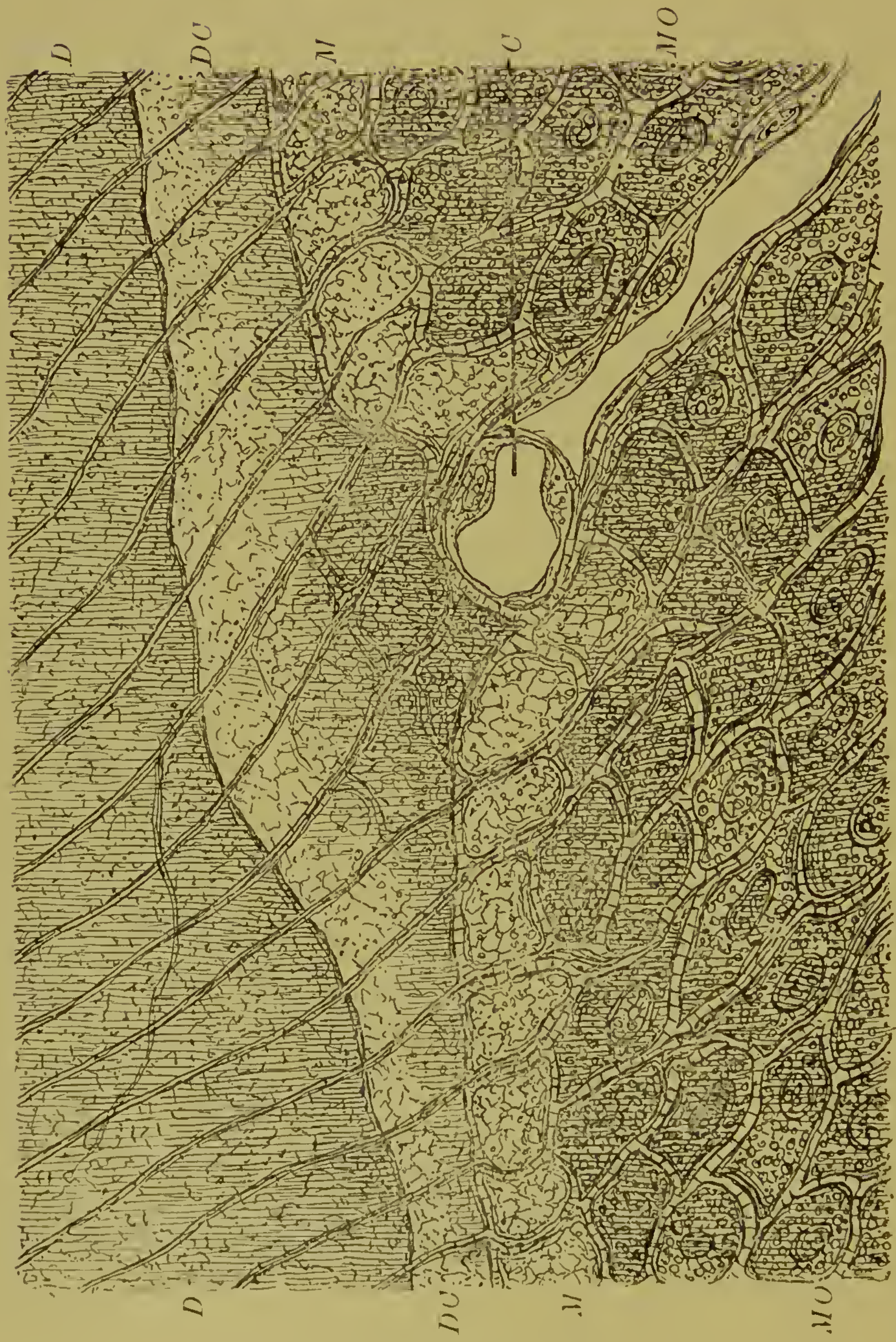
Fig. 87.



Tooth of a Human Foetus Six Months Old.

D, *D*, calcified and stratified dentine; *DC*, *DC*, non-calcified dentine, the border of the calcified dentine being marked by globular formations; *O*, odontoblasts splitting into medullary corpuscles toward the dentine, and showing rows of such corpuscles at the distal ends; *M*, medullary corpuscles ready for the transformation into basis-substance of dentine; *P*, *P*, myxomatous tissue of papilla. Magnified 600 diameters.

Fig. 88.



Tooth of Human Fœtus, Seven Months.

D, *D*, dentine calcified; *DC*, non-calcified basis-substance of dentine, close above the capillary blood-vessels broadened and visibly made up of medullary corpuscles; *C*, capillary blood-vessel in transverse and longitudinal section; *M*, *M*, medullary corpuscles ready for infiltration with basis-substance; *MO*, *MO*, medullary corpuscles arranged in rows for the formation of odontoblasts. Magnified 1200 diameters.

as soon as the former are converted into the latter. Wherever we notice rows of medullary corpuscles at the inner ends of the odontoblasts, delicate fibrillæ are seen coursing between their rows or groups.

Since, according to our views, the myxomatous basis-substance of the papillary tissue is supplied with living matter, the same as are the so-called cells, there is no difficulty in explaining the origin of new protoplasmic bodies from the previous myxomatous basis-substance, for the benefit of continuous additions to the odontoblasts.

The facts just described are well illustrated in the developing teeth of a human fœtus from six to seven months old. (See Fig. 87.)

The cusp of the dentine shows stratification, although no odontoblasts are seen at the summit of the papilla. At the sides of the cusps. odontoblasts make their appearance, broken up into finely-granular medullary corpuscles, toward the non-calcified basis-substance of the dentine, and augmented in their bulk by rows of glistening, almost homogeneous, medullary corpuscles, toward the papillary tissue. Occasionally we meet with a basis-substance of dentine not yet calcified, and still exhibiting its composition of medullary corpuscles. (See Fig. 88.)

Upon studying this specimen, all doubts as to the origin of the basis-substance of the dentine must vanish. All previous attempts at explaining how the odontoblasts are converted into dentine must prove futile in the face of such a specimen. Although we admit that such a plain instance is only exceptionally seen, we thought it to be so instructive and so convincing that we had an illustration made with a very high power. With the facts advanced, a hitherto mooted question seems to have found solution.

As to the question why dentine in all its stages of development appears to be a continuous mass, and but exceptionally interrupted by marks of stratification, the explanation is that the odontoblasts themselves are continuous. Not that the original odontoblasts are preserved and augmented from the periphery toward the center; but all that is converted of an odontoblast into dentine, at its peripheral portion, is made good by the addition of medullary corpuscles at their central ends or portions, from the tissue of the papilla,—protoplasmic bodies and basis-substance, both.

CHAPTER XV.

DEVELOPMENT OF THE ENAMEL.*

THE history of the development of the tissues of the teeth is not intelligible on the basis established by the researches of Remak. According to this observer, the epiblast and the hypoblast are epithelial formations, and give rise to epithelial tissues and their derivations only. The mesoblast is connective tissue, including the muscles, the blood-vessels, and the lymph-vessels. Early investigators in embryology were embarrassed in attempting to explain the origin and formation of the central nervous system (brain and spinal cord), which unquestionably has its origin in the epiblast, although in full development it contains a large amount of connective tissue, and blood-vessels, which are intermixed with nerve-substance proper, such as the gray substance, the ganglionic corpuscles, and the axis-cylinders. For that portion of the epiblast which gives rise to the nerve-centers, some authors have proposed the name "neuro-epithelium." This would imply that from an original epithelial structure, tissues may arise which have no resemblance to epithelia, and do not contain any, except in the ventricular lining of the brain and the central canal of the spinal cord. It is admitted, therefore, that a certain portion of the epithelium of the embryo contains protoplasm, which, in turn, becomes gray substance, forms the ganglionic corpuscles and axis-cylinders, as well as the investment of the latter,—the myelin or nerve-fat,—and the perineurium or neuroglia, which all authorities admit to be a delicate fibrous connective tissue.

The history of the development of the enamel likewise furnishes striking proofs of the fact that the theory of exclusiveness, so far as the epiblast is concerned, is not tenable. We have demonstrated that the original epithelial cord of the enamel-organ serves for carrying a certain amount of building material into the depth of the connective tissue. This material, however, loses its epithelial nature as soon as it gives rise to the enamel-organ proper, which is myxomatous connective tissue. The fact was established that the tissue termed enamel is epithelial in its origin only, and that it is changed from its original character shortly before becoming enamel proper. We must admit that enamel will not be formed unless upon an epithelial basis, the epithelium in this instance being the conveyer of the protoplasm from which enamel originates. But to assert that enamel is an epithelial structure throughout, would be as erroneous as to call the brain and the spinal cord epithelial structures.

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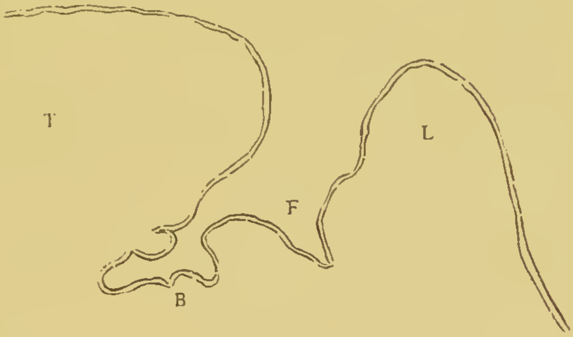
* "Contributions to the History of Development of the Teeth." By C. Heitzmann and C. F. W. Bödecker. *The Independent Practitioner*, vols. viii and ix.

From an organo-genetic point of view, we may say that the outer senses of the animal organism, serving for perceptions from the outer world, are formations of the outer investment of the animal, its epiblast. The brain, being the most highly perfected organ of sensual perception, continuously takes its growth from the epiblast. The same may be said of the teeth, which, in some lower order of amphibious organisms, such as Chelonia, are nothing but horny ledges, or a thickening of the epithelium. Even at the height of development their growth is continuous from the epiblast, and they are, at least as far as the enamel is concerned, derivations from it.

FIG. 89.



HUMAN EMBRYO SIX WEEKS OLD. FRONTAL SECTION.

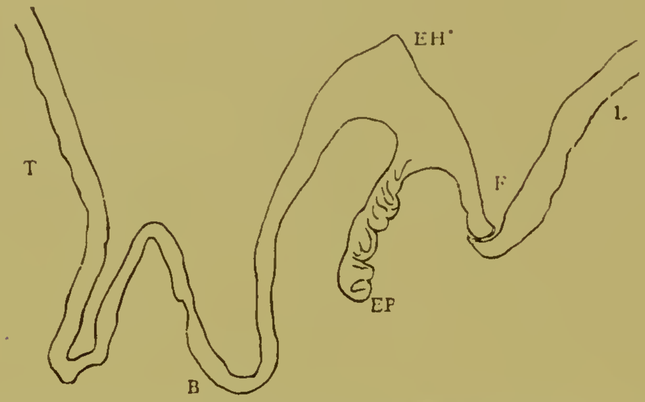
T, tongue; *L*, lip; *B*, base of oral cavity; *F*, furrow, in transverse section, funnel-shaped. Magnified 25 diameters.

Let us now consider the direction taken by the epithelial cord of the enamel-organ into the depth of the connective tissue, up to the time when the enamel-organ is ready for the formation of the enamel. The first trace of the future tooth in the human embryo is visible about the sixth week of intra-uterine life, when the epithelium of the oral cavity is as yet little developed. Here we notice a furrow, which is situated close behind the lip, and is succeeded by an elevation of medullary tissue. (See Fig. 89.)

After this period follows the formation of an epithelial peg, appearing not at the bottom of the primitive dental furrow, but at some distance from the latter. This peg appears as a reduplication of the epithelial layer covering the elevation behind the furrow. (See Fig. 90.)

Shortly afterward, the epithelial hill has gained in height considerably, and from the point which connects the hill with the rest of the oral epithelium, the original peg has elongated into an epithelial cord. A striking feature of this cord is that from its periphery arise blunt or slightly-pointed offshoots, while at the same time its distal end is noticeably broadened, the epithelia being arranged in radiating tracts throughout, but most markedly in the club-shaped enlargement of the distal end. (See Fig. 91.)

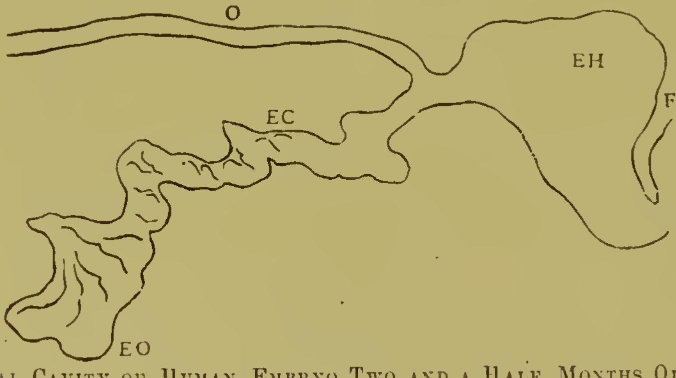
FIG. 90.



BASE OF ORAL CAVITY OF HUMAN EMBRYO TWO MONTHS OLD. FRONTAL SECTION.

T, tongue; *L*, lip; *B*, base of oral cavity; *F*, furrow; *EH*, epithelial hill; *EP*, epithelial peg. Magnified 25 diameters.

FIG. 91.

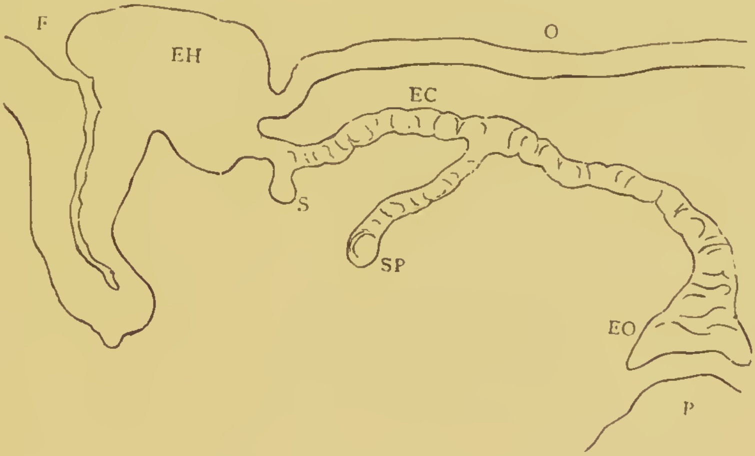


BASE OF ORAL CAVITY OF HUMAN EMBRYO TWO AND A HALF MONTHS OLD. FRONTAL SECTION.

EH, epithelial hill; *O*, epithelial lining of base of oral cavity; *F*, furrow; *EC*, epithelial cord of enamel-organ; *EO*, club-shaped enlargement of the epithelial cord, the future enamel-organ. Magnified 25 diameters.

In the third month of embryonal life, the epithelial hill still remains a prominent formation. From the point of its junction with the other epithelium arises the epithelial cord, which varies, to some extent, both in width and in its course. Sometimes the cord runs nearly parallel with the base of the oral cavity, becoming devious on the way to its club-shaped distal end. Its periphery is slightly fluted, and from its lower contour arise scanty but strongly-marked epithelial offshoots, the significance of which is not perfectly plain. We may assume that a large secondary offshoot forms the epithelial cord of a future permanent tooth, but as to the significance of the short secondary offshoots we can only suggest that the epithelium primarily producing the cord at first assumed a direction which afterward was changed. This much is certain, that such short secondary offshoots perish and disappear in the course of further development. It would certainly be a bold hypothesis to consider all such short secondary offshoots germs of supernumerary teeth, or of third dentitions. They are too common as compared with the rare cases in which supernumerary teeth are found. At this stage of development the first trace of the papilla (the future dentine) is noticeable. (See Fig. 92.)

Fig. 92.

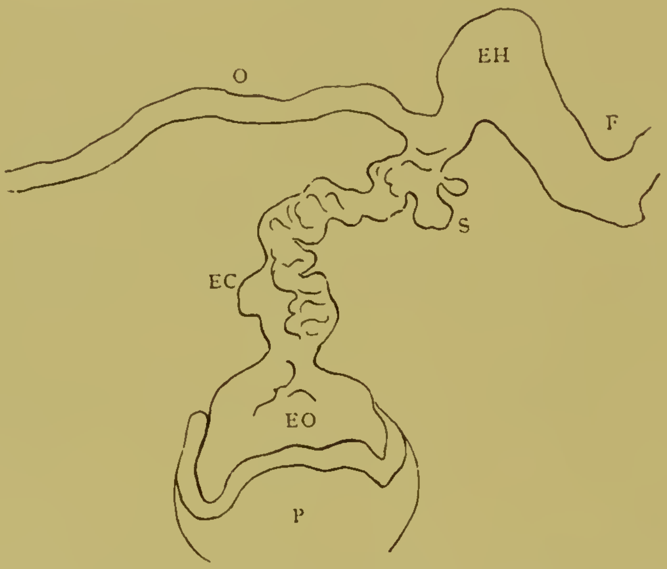


Base of Oral Cavity of a Human Embryo Three Months Old.

EH, epithelial hill; *F*, furrow, sharply marked and lined by a heavy layer of flat epithelium; *O*, base of oral cavity; *EC*, epithelial cord; *EO*, club-shaped end of the epithelial cord, the future enamel-organ; *S*, secondary offshoot; *SP*, secondary offshoot, possibly a germ of the permanent tooth; *P*, papilla. Magnified 25 diameters.

Sometimes the epithelial cord is broad, exhibiting comparatively few blunt secondary offshoots. Its course is more or less vertical, into the depth of the connective tissue of the jaw. The epithelium within the cord is arranged into groups separated by trabeculæ somewhat resembling those of true myxomatous connective tissue. The club-shaped end of such a cord at this period shows a slight separation of the columnar epithelium into an outer and an inner layer, whereas the center of the club-shaped enlargement is occupied by medullary corpuscles, which as yet do not exhibit the characters of a myxomatous reticulum. Unquestionably, this medullary tissue has arisen from epithelia, which originally filled the club-shaped end of the cord, and it is this medullary tissue from which, soon afterward, the myxomatous reticulum of the enamel-organ proper originates. (See Fig. 93.)

Fig. 93.



Floor of Oral Cavity of a Human Embryo Three Months Old.

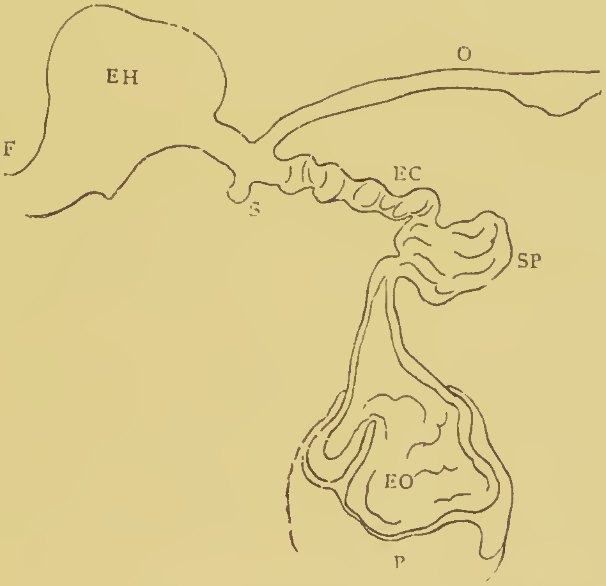
EH, epithelial hill; *F*, furrow; *O*, oral epithelium; *EC*, epithelial cord: *S*, short secondary offshoot; *EO*, medullary tissue of enamel-organ; *P*, papilla, detached. Magnified 25 diameters.

We found an epithelial cord of a three-months' embryo presenting points of interest, since it showed evidences of the germ of a temporary molar. A short offshoot arose at the place of origin of the epithelial cord, while the latter made a few shallow convolutions and then abruptly turned downward in a direction almost at right angles to its former course.

At the place of the turn a broad epithelial layer was perceptible, showing the rather thin epithelial tracts before alluded to, and in part, toward the adjacent medullary tissue, indistinctly bordered. The club-shaped end of the epithelial cord was divided into two segments by an intervening deep fissure. The broadest segment, again, showed blunt protuberances, to which corresponded shallow hills of the subjacent papilla. The club admitted of an indistinct differentiation into an external and internal epithelium, whereas its center exhibited a few faint tracts of epithelia and a large amount of medullary tissue, which as yet had nowhere begun the formation of a myxomatous reticulum. (See Fig. 94.)

When the embryo has reached about the fourteenth week, the epithelial cord is of special interest, on account of the appearance of two distinct layers at its distal end, the internal and the external epithelium, between which the myxomatous enamel-organ makes its appearance. The papilla, at this point of development, has a distinct neck, being of a mushroom shape. At its distal periphery it is bordered by a thin layer of fibrous connective tissue extending upward along the external epithelium to a certain height, and producing what has been termed the follicle, or tooth-sac. In one of our specimens the epithelial cord emanates with a broad base from the epithelial

Fig. 94.



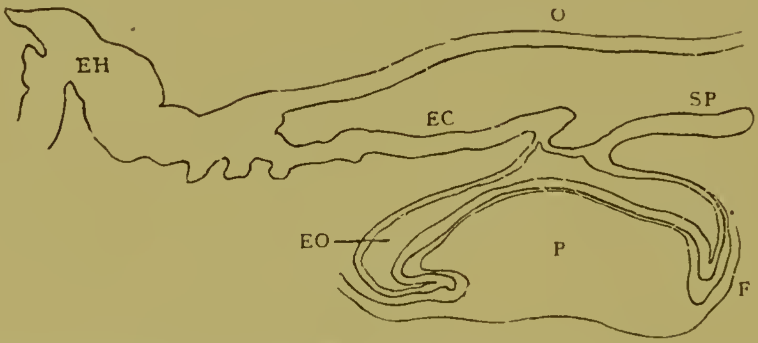
Base of Oral Cavity of a Human Embryo Three Months Old.

EH, epithelial hill; *F*, furrow; *O*, oral epithelium; *EC*, epithelial cord of enamel-organ; *S*, short secondary offshoot; *SP*, broad secondary offshoot, possibly the germ of a permanent molar; *EO*, club of the epithelial cord filled with medullary tissue (the future enamel-organ); *P*, papilla. Magnified 25 diameters.

hill, having at this point several short and blunt offshoots directed downward. Its general course is almost parallel to the floor of the mouth. The enamel-organ originates from its distal end in an abrupt rectangular manner, with a somewhat narrow neck. The external epithelium extends into a solid peg, with a slight sigmoidal curvature, obviously the germ of the future permanent tooth. (See Fig. 95.)

In another specimen of the same period, the epithelial cord arises from the base of the epithelial hill, with a narrow neck, in immediate connection with a solid epithelial peg, running a downward vertical course, with a slight sigmoidal curvature. The epithelial cord itself shows blunt offshoots upward as well as downward, the former being characterized by a distinct concentric arrangement of their epithelia. The general course of the epithelial cord is slightly downward. Its cup-shaped distal end is marked by three prolongations, the concavities of which correspond to two myrtle-leaf-shaped papillæ. Evidently, this is the germ of a future temporary molar. No trace of a corresponding permanent tooth was visible at the distal end of the epithelial cord. The external epithelium is very broad, and visible only along the broad cup. The enamel-organ is narrow, but possesses a pronounced myxomatous structure. (See Fig. 96.)

FIG. 95.



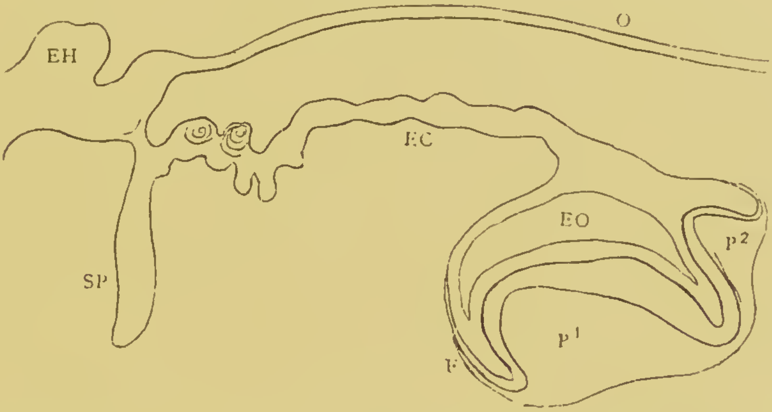
BASE OF ORAL CAVITY OF A HUMAN EMBRYO THREE AND A HALF MONTHS OLD.

EH, epithelial hill; *O*, oral epithelium; *EC*, epithelial cord; *SP*, secondary offshoot of a permanent tooth, arising from the external epithelium of the enamel-organ; *EO*, enamel-organ of a distinctly myxomatous character; *P*, papilla; *F*, follicle. Magnified 25 diameters.

The fourth month of embryonal life differs from the previous stage only as the myxomatous enamel-organ gains considerably in volume, with a simultaneously-marked differentiation into its two boundary layers, the external and the internal epithelium. The papilla, at this stage, likewise, has gained in bulk.

and its enveloping layer of fibrous connective tissue extends farther up along the convexity of the cup of the enamel-organ. In one of the specimens, the epithelial hill is extremely marked, and contains a central vacuole, possibly the first step toward its destruction, since shortly afterward no trace of it is found.

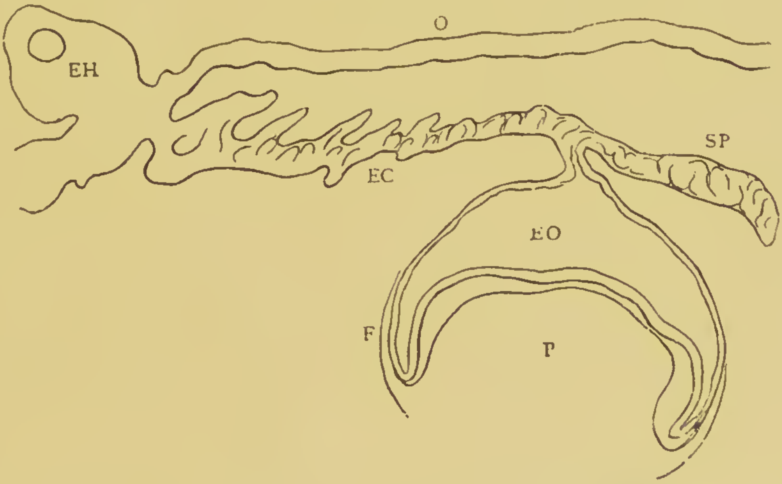
FIG. 96.



FLOOR OF ORAL CAVITY OF A HUMAN EMBRYO THREE AND A HALF MONTHS OLD.

EH, epithelial hill; *O*, oral epithelium; *EC*, epithelial cord of enamel-organ; *SP*, secondary offshoot, possibly the germ of the permanent tooth; *EO*, enamel-organ; P^1 and P^2, double papilla; *F*, follicle. Magnified 25 diameters.

FIG. 97.



FLOOR OF ORAL CAVITY OF A HUMAN EMBRYO FOUR MONTHS OLD.

EH, epithelial hill; *O*, oral epithelium; *EC*, epithelial cord with numerous offshoots; *SP*, secondary peg of permanent tooth; *EO*, myxomatous enamel-organ; *P*, papilla; *F*, follicle. Magnified 25 diameters.

The epithelial cord begins with a narrow neck, and has numerous oblique secondary offshoots, mainly at its upper periphery. The arrangement of the epithelia into tracts is marked along the epithelial cord, not only of the temporary but also of the permanent tooth. (See Fig. 97.)

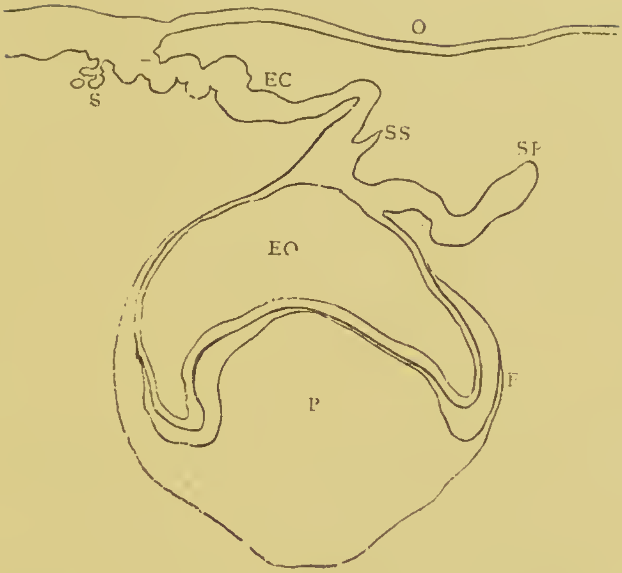
In another specimen of the same age, the epithelial hill is absent. The cord has but a limited number of offshoots, some of which are pediculated, and some have the shape of a lancet. The peg of the permanent tooth is conspicuous by its devious course. (See Fig. 98.)

When the embryo is at the age of four and a half months, the development of the enamel-organ has still further proceeded; its myxomatous tissue is plainly marked, and the papilla has correspondingly gained in bulk. The specimen illustrated is noteworthy for its short vertical epithelial cord, which is directly in connection with the lining epithelium of the oral cavity. The secondary offshoots are but short, and no trace of a peg for the permanent tooth is visible in this section. The cup of the enamel-organ is lobulated, evidently belonging to a future molar. (See Fig. 99.)

The next question to be considered is, How does epithelium grow from an originally small point into a comparatively long epithelial cord? Most observers agree that epithelium has an independent growth, and that its elements by division and multiplication will produce epithelium, and no other tissue. During the last fourteen years many microscopists have studied the so-called indirect division of "individual cells," which became traceable after the application of certain reagents, especially safranine. This dye rendered visible a filamentous structure in the nucleus, apparently independent of the surrounding protoplasm, which did not take up the stain of the safranine. The filaments produced beautiful star-shaped figures, with equatorial divisions leading to a fission of the original nucleus, and the process has been termed *karyokinesis* or *mitosis*.

In fresh specimens, or those preserved in a chromic-acid solution, the filamentous structure of the nucleus does not exist, or, at least, is not plainly visible, although Bizzozero, of Italy, claimed that safranine will bring out the filamentous structure of the nucleus even in chromic-acid specimens. The filaments taking up the dye were termed chromatin, and all those remaining pale, achromatin; and it was claimed that these were two different substances. Considering the fact that the filaments are produced only by certain reagents, we should be loth to assume that the structure thus rendered visible really corresponds to the unstained and living epithelium. The doubts become still stronger, if we recall the fact that living matter is

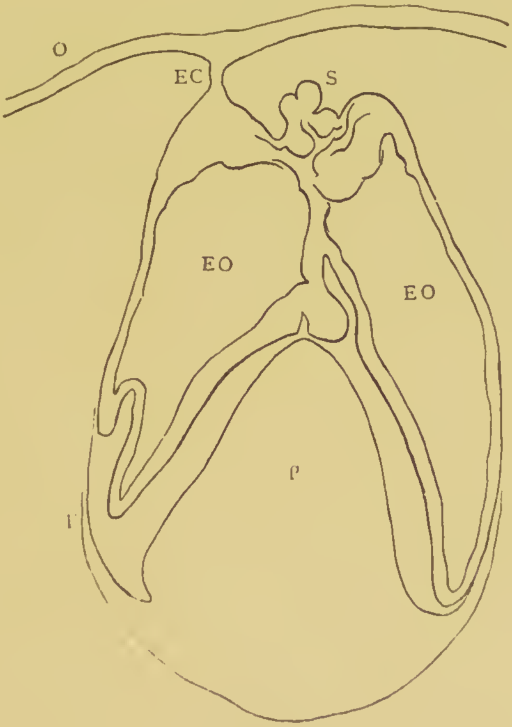
FIG. 98.



FLOOR OF ORAL CAVITY OF A HUMAN EMBRYO FOUR MONTHS OLD.

O, oral epithelium; *EC*, epithelial cord; *S*, short pediculated offshoot; *SS*, secondary offshoot, lancet-shaped; *SP*, secondary peg of permanent tooth; *EO*, enamel-organ; *P*, papilla; *F*, follicle. Magnified 25 diameters.

FIG. 99.



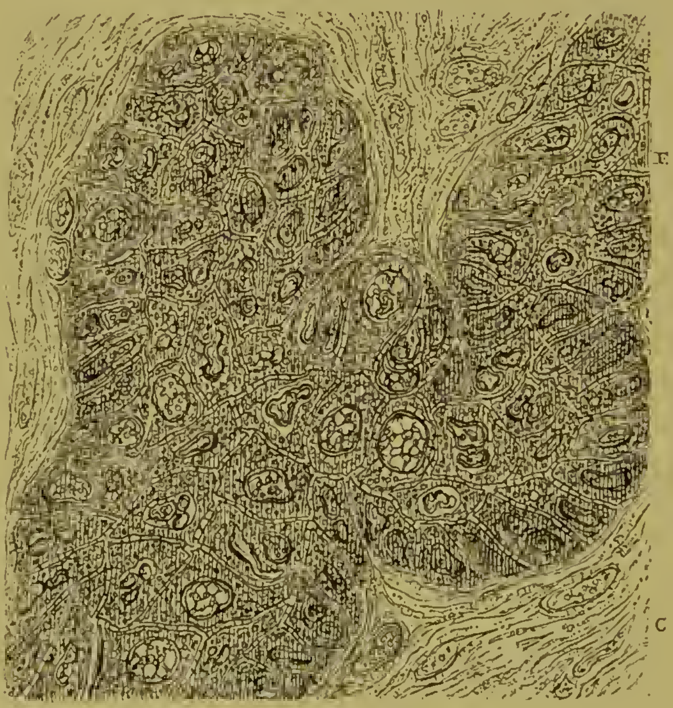
ENAMEL-ORGAN AND PAPILLA OF HUMAN EMBRYO FOUR AND A HALF MONTHS OLD.

O, oral epithelium; *EC*, short epithelial cord; *S*, secondary offshoot; *EO*, enamel-organ; *P*, papilla; *F*, follicle. Magnified 25 diameters.

stained deeply by the same reagent, if present in a compact mass, where thin layers of it remain unstained, as is the case in the protoplasm which surrounds the central nucleus. From this point of view the terms chromatin and achromatin become superfluous, especially if we admit that the living matter during life is in constant motion, particularly in the process of growth, although its continuity may temporarily be interrupted.

What we see in a growing epithelial cord, with high powers of the microscope, is depicted in Fig. 100.

Fig. 100.



Epithelial Cord of the Enamel-Organ of a Human Embryo Three and a Half Months Old.

E, epithelial cord; *C*, connective tissue. Magnified 800 diameters.

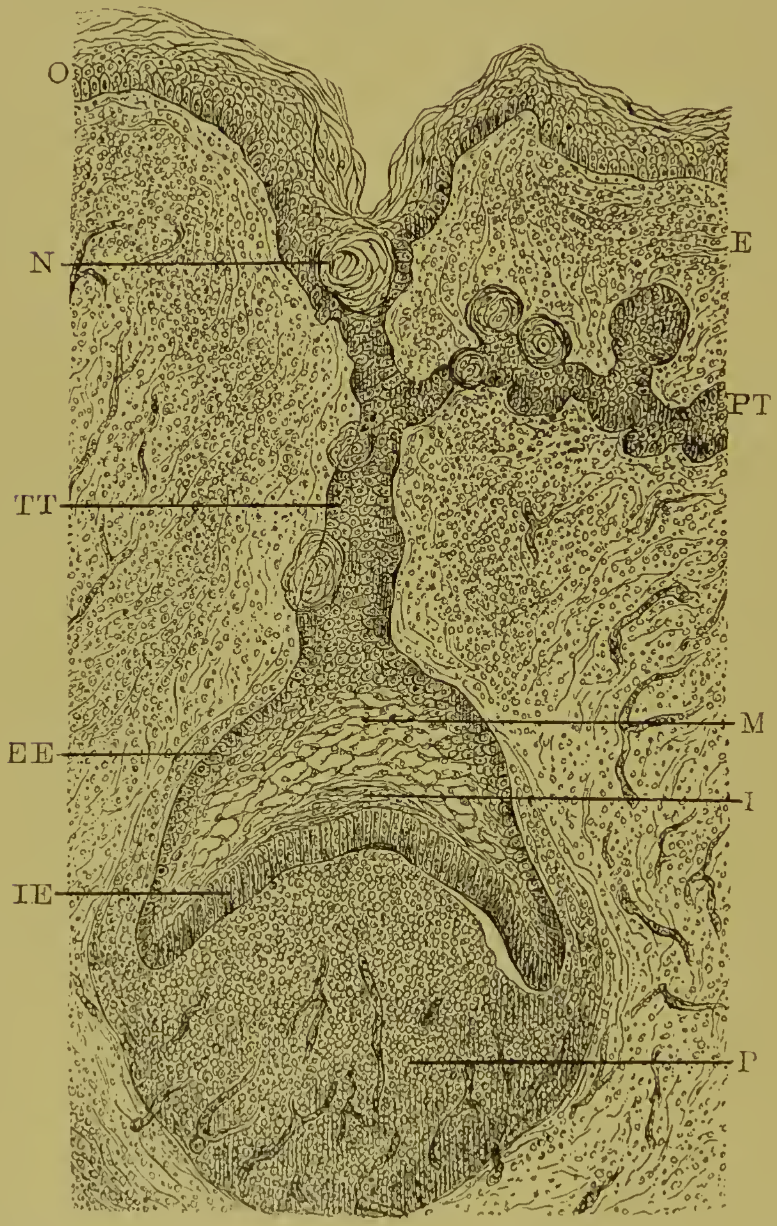
We observe epithelia along the borders of the cord which are elongated and bear the name of columnar epithelium; while the central portion is filled with epithelia which exhibit about an equal diameter in all directions, and are termed cuboidal. Both varieties show differences in the size and structure of their nuclei. Some nuclei are very large and distinctly reticular, others are small and nearly compact, often appearing as if split up into several lumps, with a vacuole or plasmatic space. Sometimes a nucleus is elongated or irregular in shape, another being globular or vesicular. Again, we see epithelia much enlarged, holding in their interior several nuclei. An epithelium in this condition has been termed by previous observers "the mother cell." Not infrequently we observe solid, spindle-shaped bodies in the cement-substance, between two epithelia. All these forms become intelligible only under the assumption that epithelium is composed of protoplasm, in which the living matter greatly varies in size and shape, according to the state of growth and new formation. The cement-substance is often absent, and thus large protoplasmic masses become conspicuous, with a varying number of nuclei. Where the cement-substance is present, it is usually traversed by radiating lines, which are the connecting bridges of the living matter. Again, these lines may coalesce into solid masses, presenting spindle, pear, or club shapes, from which new epithelia arise, as shown by Louis Elsberg.

The way, therefore, in which epithelium grows is by the augmentation of its living matter, and the appearance of new cement-substance,—that is, new lines of demarcation, in which process the continuity of the living matter, though temporarily interrupted in certain foci, in the whole remains preserved and unbroken. In the epithelial cord of the enamel-organ the connecting spokes in the cement-substance are prominently marked in all its layers and stages of development.

We now proceed to consider the changes of the enamel-organ about the beginning of the fifth month. If we examine the cup-shaped enlargement of the enamel-organ at this period, we observe a distinctly-marked border composed of columnar epithelia, whereas the interior of the cup is filled with medullary corpuscles, which, in the center, present the so-called stellate reticulum. At the end of the fourth and the beginning of the fifth month, we invariably find some epithelial cords, which, at their interior ends, are broadened and contain a distinctly marked stellate reticulum. (Fig. 101.)

The first question to be entered into is, Whence comes the myxomatous tissue known as the stellate reticulum in the interior of the cup? According to our present knowledge of the tissues of the mammalian organism, we are entitled to call the stellate reticulum a myxomatous tissue, which is a variety of connective tissue. This tissue occurs most extensively in the embryonal organism, and remains throughout life in the fully-developed body only in a limited number of organs, such as the pulp of a tooth, the lymph-ganglia, and the so-called adenoid tissue, which properly ought to be called lymph-tissue, and is

FIG. 101.



EPITHELIAL CORD TERMINATING IN THE ENAMEL-ORGAN. HUMAN EMBRYO AT THE END OF THE FOURTH OR THE BEGINNING OF THE FIFTH MONTH OF INTRA-UTERINE LIFE.

O, stratified epithelium of the oral cavity; *TT*, epithelial cord of temporary tooth; *PT*, epithelial cord of permanent tooth; *N*, epithelial nests and buds at the bottom of the furrow and along the cords of both the temporary and permanent teeth; *M*, myxomatous tissue of the enamel-organ (stellate reticulum); *EE*, external (outer) epithelium; *IE*, internal (inner) epithelium; *I*, intermediate layer between inner epithelium and myxomatous tissue; *P*, papilla with numerous blood-vessels; *E*, embryonal or medullary tissue crowded with medullary corpuscles at a certain distance from the epithelial formation. Magnified 50 diameters.

distributed throughout the mucous membranes, especially during the early periods of life. Unless we assume that the enamel-organ is a tissue entirely different from all others entering into the structure of the body, we must call it myxomatous connective tissue.

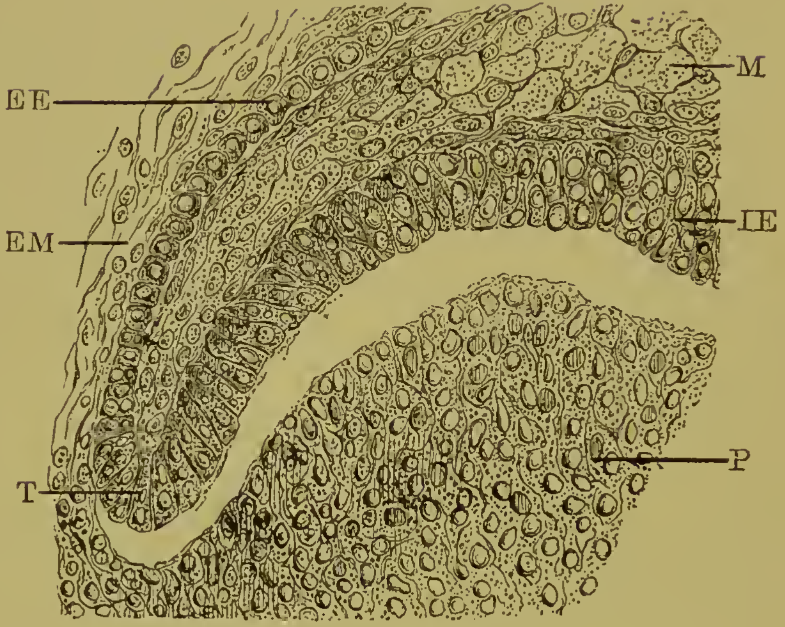
Those who adhere strictly to the teachings of Thiersch and Waldeyer will be loth to admit that epithelium can ever change into connective tissue. Researches thus far, however, have led us to the conviction that such a transformation is by no means impossible. The thyroid gland, for instance, is originally composed of alveoli lined by epithelia. Shortly after birth, however, the epithelium is replaced by a medullary or lymph-tissue. The whole central nervous system (the brain and spinal cord) originates from the embryonal epiblast, which is strictly epithelial in nature. Nevertheless, nobody will maintain that the central nervous system, so richly supplied with blood-vessels, is an epithelial structure, except in the lining of the ventricles of the brain, and the central canal of the spinal cord. There may be advocates of the exclusive nature of epithelial tissue who might think of an immigration of medullary corpuscles between the epithelia of the enamel-organ for the benefit of the formation of the stellate reticulum, but there is not the least indication of such a process in any of our specimens. On the contrary, we can prove a gradual transformation of the epithelia into myxomatous tissue.

In the third month of intra-uterine life, we observe, inside of the epithelial cup of the enamel-organ, a zone entirely occupied by medullary corpuscles, and even in the fourth and fifth months such a gradual transition is distinctly traceable (Fig. 102).

Those who still adhere to the cell doctrine will never be able to understand how medullary tissue arises from epithelia. According to our views, however, there exist no individual cells, but layers of protoplasm, in which the living matter is distributed in a reticular arrangement. Every particle of the living matter is able to grow from the size of a minute granule to that of a solid lump, in which afterward takes place a differentiation into a peripheral protoplasm containing comparatively little living matter, and a central body, termed nucleus, with a larger amount of living matter.

The inner epithelia, at the period mentioned above, exhibit augmented nuclei and small glistening granules near the fold,

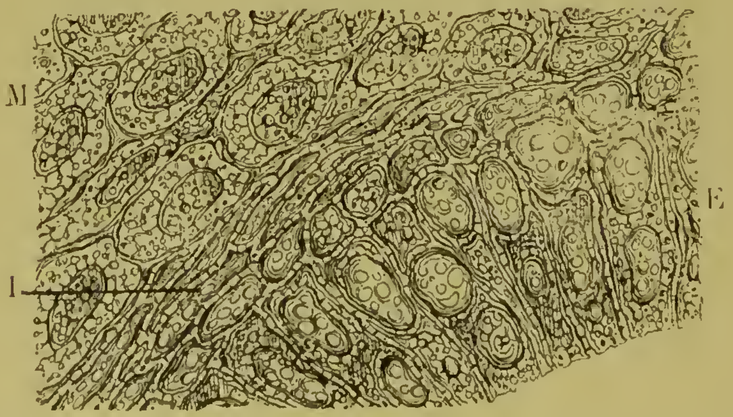
Fig. 102.



Lower Edge of the Cup of the Enamel-Organ, showing the Recurvation of the External into the Internal Epithelium, at the End of the Fourth Month of Intra-Uterine Life.

EM, embryonal or medullary tissue; *EE*, external epithelium, composed of cuboidal epithelia; *T*, cuboidal epithelia turning into columnar epithelia; *IE*, inner epithelium breaking down into medullary tissue and giving rise to the spindles composing the intermediate layer, close above the internal epithelium; *M*, myxomatous tissue, or stellate reticulum, bounded toward the external and internal epithelium by the intermediate layer, and continuous with the medullary tissue filling the border of the cup; *P*, papilla. Magnified 500 diameters.

Fig. 103.



Inner Epithelium of the Enamel-Organ of a Human Embryo of Four Months of Intra-Uterine Life.

E, inner epithelia connected with each other by delicate thorns, traversing the cement-substance. In their interior vacuoled lumps are seen of greatly varying sizes, which toward the enamel-organ are split up into smaller reticulated corpuscles, all being interconnected by delicate offshoots; *I*, intermediate layer composed of spindle-shaped medullary corpuscles; *M*, beginning formation of the myxomatous reticulum, in the meshes of which we observe nucleated protoplasm. Magnified 1200 diameters.

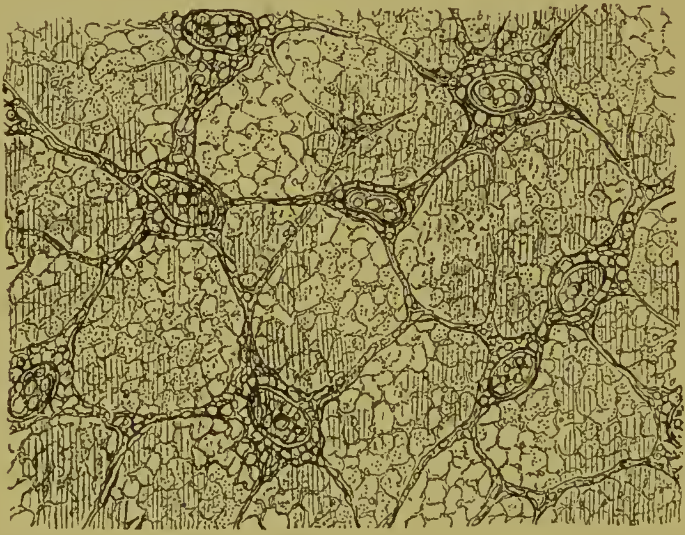
corresponding in position to the neck of the future tooth. The more we turn to the center of the cup, the more shall we be struck by the presence of glistening homogeneous lumps in the epithelia, until we have reached the center of the cup, where we observe that epithelium has been transformed into a number of such lumps in a regular arrangement, which reminds us of their origin from previous epithelia. The original epithelia gradually become enlarged, and at last are split up into a number of medullary corpuscles. As a rule, this process of transformation is most marked in the original epithelia at the portion directed toward the stellate reticulum, whereas, in that portion nearest the papilla, the epithelial character may still be preserved. (Fig. 103.)

The medullary corpuscles first assuming a spindle shape, constitute the intermediate layer (*stratum intermedium*). The innermost spindles are in connection with a comparatively coarse net-work, representing the first trace of the stellate reticulum. The trabeculæ of this reticulum are composed of solid or vacuoled spindles, inclosing spaces which appear to be filled with a distinctly reticulated protoplasm, holding central nuclei. The latter exhibit a varying number of coarser granules, the so-called nucleoli.

Not infrequently the intermediate layer is missing, which fact affords the best opportunity for observing the gradual transition of the homogeneous globules arising from the epithelia into nucleated protoplasmic bodies, and finally into the myxomatous reticulum. Changes similar to those described take place in the central portions of the external epithelia, and, as it seems, even precede the changes of the inner epithelia. Thus the original columnar bodies of the outer epithelium are reduced to a row of cuboidal epithelia, as seen in Fig. 102, *EE*. The medullary corpuscles are slightly enlarged: their nuclei, at first plainly visible, are likewise split up into a delicate reticulum, and both become infiltrated with a myxomatous basis-substance. The peripheral portions of the original medullary corpuscles, on the contrary, are solidified into nucleated formations of living matter, representing the stellate reticulum proper. The meshes of the myxomatous tissue in the stellate reticulum are originally small, and correspond in size to the medullary corpuscles, from which they arose. The corpuscles of the stellate reticulum are mostly solid. ater, several medullary corpuscles are required for the formation of a large field of basis-substance. The original stellate reticulum, in this view, must fall back to an embryonal or medullary tissue before changing into a more perfect myxomatous tissue, such as we observe from the end of the fifth month of fœtal life up to the full development of the enamel. (Fig. 104.)

Toward the end of the fourth and the beginning of the fifth month, the stellate reticulum is composed of nucleated protoplasmic bodies, with a varying number of branching and interconnecting offshoots. With low powers of the microscope, the basis-substance in the meshes, inclosed by the corpuscles and their offshoots, appears to be homogeneous and structureless. The highest powers, however, reveal in this basis-substance the presence of a delicate reticular structure, even without the addition of any reagent. This structure has arisen by a direct transformation of the original medullary corpuscles into basis-substance. In the highest development of the stellate reticulum, such as seen in the seventh and eighth months of fœtal life, the nucleated corpuscles are more slender, and the reticulum is composed mainly of delicate branching and interconnecting fibers.

Fig. 104.

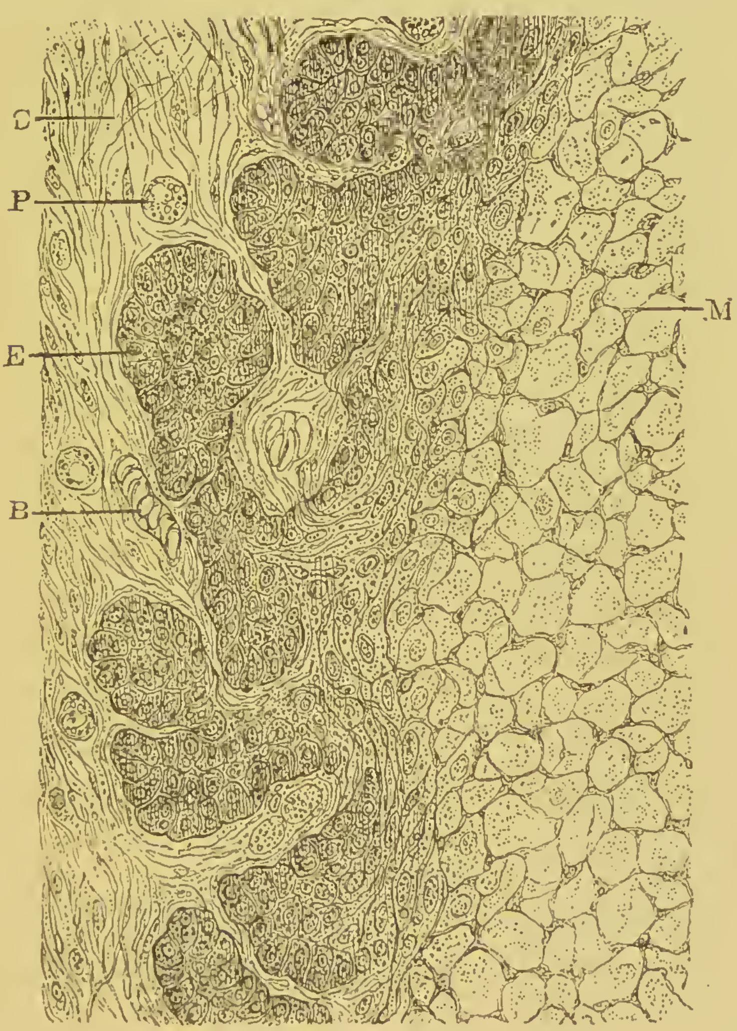


Stellate Reticulum, or Myxomatous Tissue, of the Enamel-Organ of a Human Fœtus of Five Months of Intra-Uterine Life.

Magnified 1200 diameters.

The further changes of the external epithelium are of considerable interest. While about the fourth month of intra-uterine life the inner portions of the external epithelium are, as mentioned above, transformed into medullary tissue and participate in the formation of the myxomatous enamel-organ, a single row of cuboidal epithelia is left. From the remains of this external epithelium, a new growth takes place, of a markedly centrifugal character. By a multiplication of the epithelial elements, solid buds and knobs are formed, well known to previous observers. (Fig. 105.)

Fig. 105.



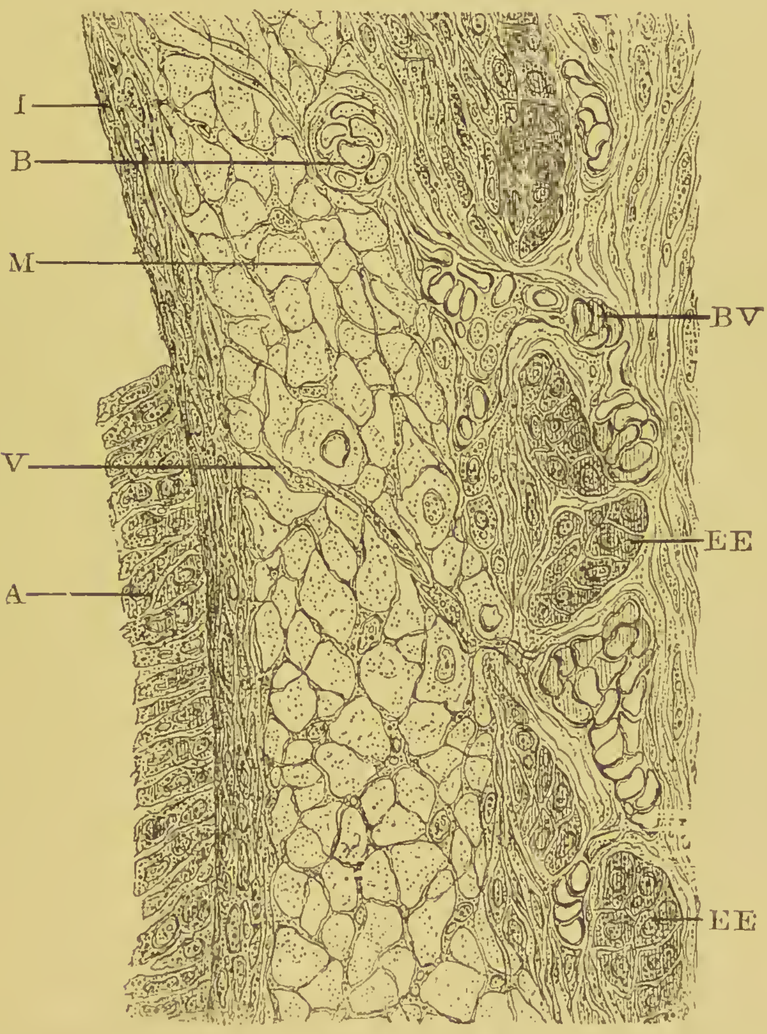
Budding of the External Epithelium of the Enamel-Organ of a Human Fœtus Seven Months Old.

M, myxomatous reticulum of the enamel-organ; *C*, delicate fibrous connective tissue; *E*, epithelial bud arisen from the external epithelium; *P*, large protoplasmic body filled with glistening coarse granules; *B*, newly-formed blood-vessel. Magnified 500 diameters.

These buds are at first in continuity with the external epithelium, and have a distinct layer of outer columnar and a varying number of inner layers of cuboidal epithelia. They are characterized by a brownish color, common to all epithelial formations. We observe that, both in the central portions of these buds and along the original row of the external epithelium, a transformation takes place into medullary corpuscles, the same as we observe toward the myxomatous enamel-organ. This medullary tissue develops into connective tissue of a decidedly fibrous character. Thus we observe numerous interruptions in the external epithelium, partly filled with medullary and partly with fibrous connective tissue. The latter is in direct connection with the myxomatous reticulum, or this connection is established by spindle-shaped corpuscles, resembling those of the intermediate layer close above the internal epithelium.

At the time when the buds sprout from the external epithelium, an active new formation of blood-vessels and blood-corpuscles takes place in the immediate vicinity of the buds. At first we notice large protoplasmic bodies with coarse granules, which were known to Theodore Schwann, in 1839, by the name of blood-cells. With the increase of the size of these bodies, the granules likewise become coarser, and assume the properties of the so-called hæmatoblasts. These grow up to the size of red blood-corpuscles, and we not infrequently encounter in the bays between the buds, groups of hæmatoblasts, or fully-developed blood-corpuscles, apparently isolated and in no connection with blood-vessels. At last, capillary blood-vessels arise from the conference of blood-cells, which are filled with red blood-corpuscles. The splitting of the external epithelium into isolated buds and nests of an epithelial character is especially marked near the neck of the future tooth. (Fig. 106.) At this place the amount of myxomatous enamel-organ in a seven-months fœtus is usually small, since a great quantity of it has already been transformed into enamel-tissue. But even here a few small and isolated epithelial nests are seen, surrounded by a large number of capillary blood-vessels, filled with blood-corpuscles. It is evident that all these blood-vessels are newly formed, and indeed we can trace the formation of blood-vessels in this situation step by step. Even the myxomatous trabeculæ of the enamel-organ participate in the formation of capillary blood-vessels. We have seen closed spaces, or vesicles, sprung from the basis-substance of the myxomatous tissue, filled with hæmatoblasts and red blood-corpuscles, partly in connection with already-formed or forming capillaries. No doubt the living matter inclosed in the basis-substance has grown into hæmatoblasts. This process is indicated by the appearance either of coarsely-granular or of compact glistening nuclei in the meshes of myxomatous reticulum.

Fig. 106.

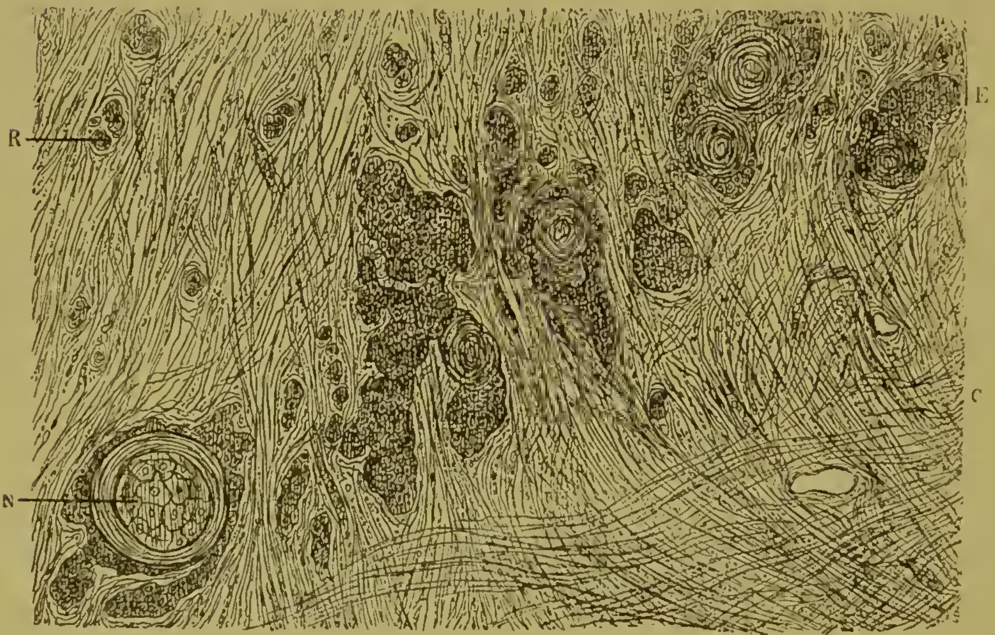


Isolated Epithelial Nests of the Place of the Enamel-Organ corresponding to the Neck of the Future Tooth of a Human Fœtus Seven Months Old.

M, myxomatous reticulum of the enamel-organ; *A*, row of ameloblasts; *I*, intermediate layer composed of spindles and fibers; *B*, vesicle filled with hæmatoblasts and red blood-corpuscles; *V*, capillary blood-vessel forming from trabeculæ of the myxomatous reticulum; *B V*, irregular spaces filled with hæmatoblasts and red blood-corpuscles, lined by endothelia and in an incomplete connection with forming capillaries; *EE*, epithelial nests, the remnants of the external epithelium. Magnified 500 diameters.

Wherever we observe epithelial nests, they are invariably enlarged, toward the enamel-organ, by spindles and fibers of an intermediate layer. Their scarcity and diminutiveness at the place corresponding to the neck of the tooth indicate that they are completely transformed into medullary tissue. Considering the fact that at the end of the intra-uterine development the enamel-organ is nearly exhausted, and the enamel which is formed up to that time is comparatively thin, there is good reason for the assumption that the medullary tissue sprung from the previous external epithelium is the source for the completion of such enamel as we observe upon temporary teeth when they emerge from their sockets.

FIG. 107.

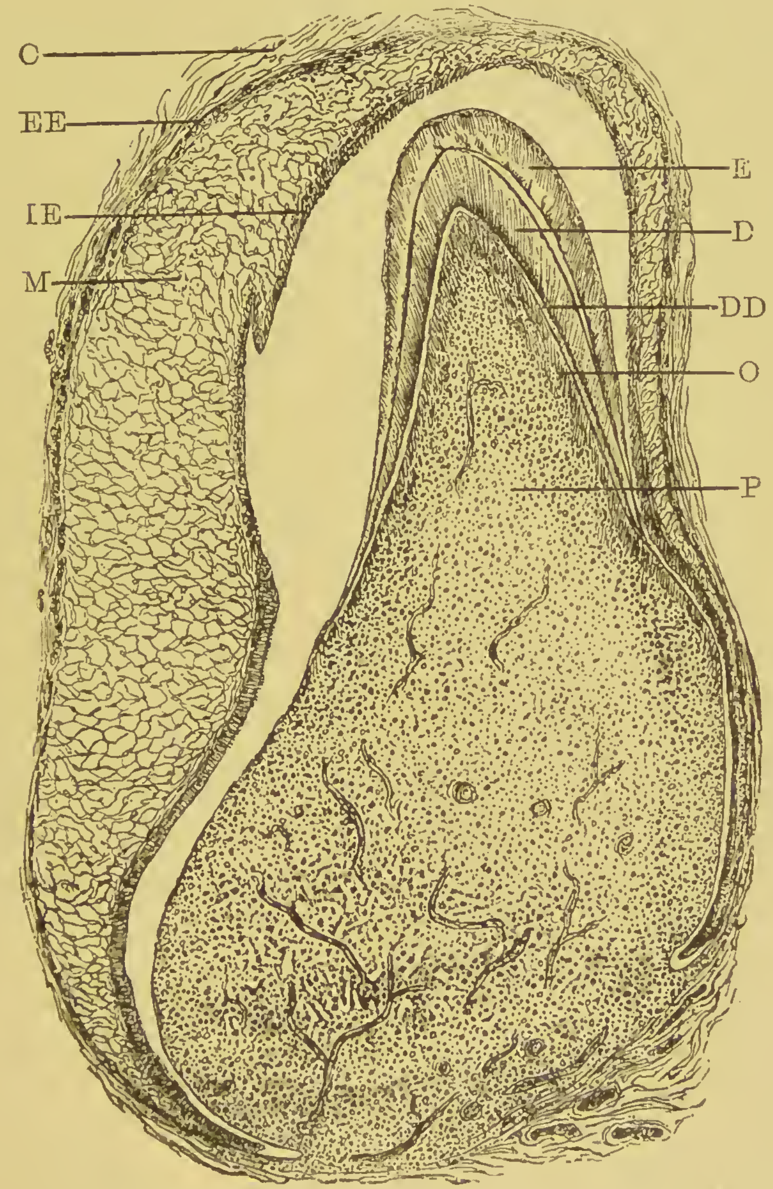


DISSOLUTION OF EPITHELIAL CORD OF THE ENAMEL-ORGAN INTO ISOLATED CLUSTERS OF A HUMAN FŒTUS FIVE MONTHS OLD. HORIZONTAL SECTION.

C, fibrous connective tissue with scanty blood-vessels; *N*, epithelial nest composed of large, flat, almost epidermal-like scales, producing onion-like layers around the central group; this nest is surrounded by tracts composed of cuboidal epithelium; *E*, clusters of cuboidal epithelia holding concentrically arranged epithelial nests; *R*, remnants of epithelia transformed into clusters of medullary corpuscles. Magnified 100 diameters.

Of special interest are concentrically stratified globular nests and buds, in which the epithelia appear flattened and arranged in the shape of an onion. Such nests are often lacking altogether, and sometimes they are present in small numbers in the center or at the periphery of the epithelial cord. Sometimes their number is very large. The centers of the nests are occasionally filled with globules of high refraction, possibly colloid material or eleidin (horn fat). In some specimens the epithelial structure of the peg is little marked, especially in places where the epithelial peg produces broadened layers, without sharp contours toward the surrounding connective tissue.

Fig. 108.



First-Formed Dentine and Enamel of Human Fœtus, Seven Months.

E, enamel-cap; *D*, calcified dentinal cap; *DD*, non-calcified dentine; *O*, row of odontoblasts; *P*, papilla, with blood-vessels; *M*, stellate reticulum of enamel-organ; *IE*, inner epithelium; *EE*, clusters of the remains of the outer epithelium; *C*, fibrous connective tissue. Magnified 50 diameters.

In such places tracts are seen composed of rows of solid nuclei, or solid cords, between which fine granular protoplasm is visible. Such tracts have been repeatedly alluded to in the description of the early forms of development of the epithelial cord of the enamel-organ. It is quite possible that in such places a transition takes place from the epithelial to the medullary, and from this to connective tissue. This is rendered probable by the fact that the broadened portions of the epithelial cord have sharp contours only on one side, whereas the opposite periphery almost blends with the adjacent connective tissue, without a distinct line of demarcation between the two kinds. While we admit that the original epithelial peg and cord are of a marked epithelial structure, at the same time we claim that in the advancing process of growth the epithelium does not retain its specific structure, but blends with or is transformed into connective tissue. (See Fig. 107.)

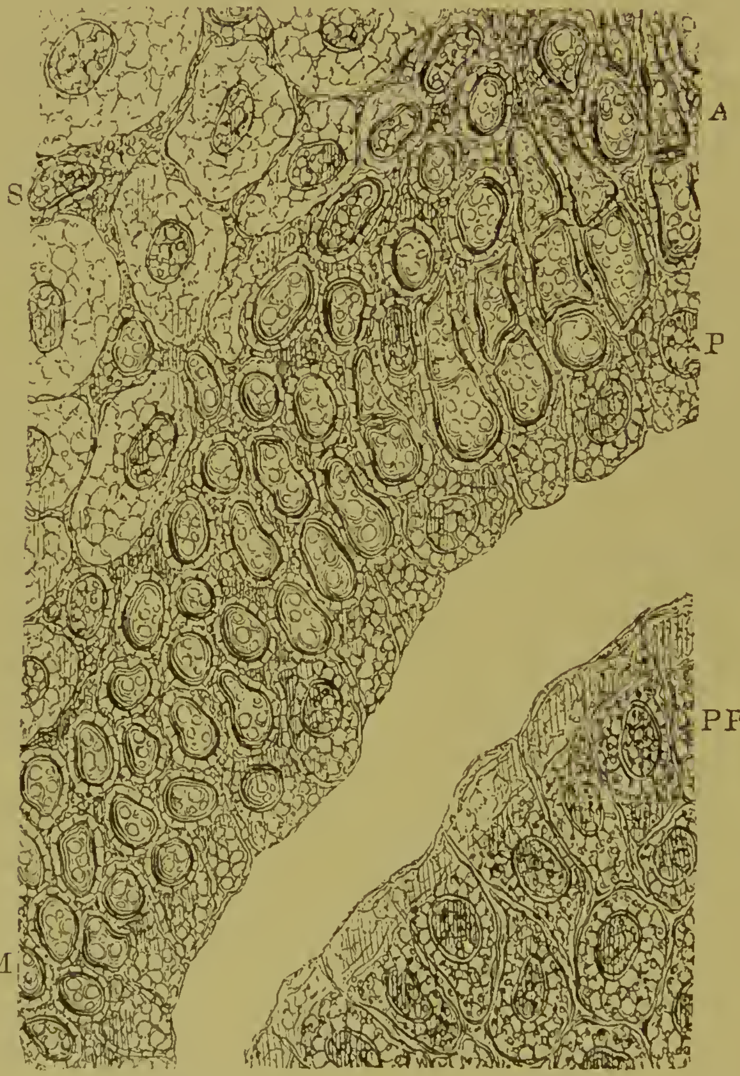
The formation of enamel commences about the sixth month of fœtal life, at a period when the dentine, which begins to form about the fifth month, has assumed a certain thickness. About the seventh month, we observe at the summit of the papilla a comparatively broad cap, the dentine, and above this a somewhat narrower layer of enamel. (Fig. 108.)

Investigations of the development of enamel are rendered difficult by the fact that the enamel-organ is almost invariably found to be detached from the enamel and the papilla. This perplexity may be obviated, at least to a certain extent, by filling the cavity between the enamel-organ and the enamel with celloidin. The cavity or space is evidently the result of shrinkage of the delicate myxomatous tissue in the enamel-organ. A peculiar asymmetry is often met with, one side being very broad and the other very narrow. Peculiar indentations, also, are often seen in the course of the inner epithelium. Whether or not all of this is artificial, and due to shrinkage, we are unable to state, but it is certain that as soon as the enamel begins to appear there are marked differences in the structure of the inner epithelium. At the bottom of the enamel-organ, corresponding to the future neck of the tooth, the inner epithelium is found to be transformed into medullary tissue, and the edge between the inner and outer epithelium is likewise filled with medullary tissue. Higher up, along the border of the papilla, where there is as yet no enamel, we find formations that resemble the original epithelia, but which in this condition are termed ameloblasts. The intermediate layer, in connection with the ameloblasts in this stage, is always markedly developed. Still higher up, where ready-formed enamel is present, the ameloblasts are much less regular, and we observe that they again split up into medullary corpuscles. From this we draw the conclusion that the original inner epithelium is transformed into medullary corpuscles, which give rise to the ameloblasts, and that the latter, before being transformed into enamel, once more break up into medullary tissue.

In a specimen prepared from a human fœtus of five months, there is scarcely a trace of the inner epithelium left: we see nothing of that tissue except a succession of small glistening medullary corpuscles, which, by their arrangement in rows, remind us of their origin from previous epithelia. This tissue remains plainly visible even in the sixth and seventh months of fœtal life, especially, as mentioned above, at the fold corresponding to the edge of the enamel-organ in the region of the future neck of the tooth. Higher up, the medullary corpuscles, which previously were scattered, once more assume a line-like arrangement, and gradually take the shape of narrow elongated corpuscles, not always distinctly nucleated, and these elongated bodies, somewhat resembling the original columnar epithelia, are termed ameloblasts. (Fig. 109.)

One of the striking features in this process of transformation is the presence of a layer forming the outermost portion of the enamel-organ toward the papilla (Fig. 109, *P*). This layer, with low powers of the microscope, appears to be made up of finely-granular protoplasm with interspersed granular nuclei. Above this, marks of division appear in the protoplasmic layer, and the marks correspond to the boundary lines of the rows of the glistening medullary corpuscles, the forerunners of the future ameloblasts. There is a transitional stage, as referred to in Fig. 109, in which the inner portions of the ameloblasts are made up of several glistening medullary corpuscles, whereas the outermost portion is finely granular, or made up of a delicate reticulum. The ameloblasts in the seventh month of fœtal life are distinctly-marked formations, and are present only on places where enamel has not yet been formed. They are in junction, side by side, from the region of the neck to the summit of the crown. They are composed of finely-granular protoplasm, with one or several nuclei, or sometimes without any distinct nucleus. Their general form is columnar, slightly broadened toward the papilla. Often, however, they exhibit parallel contours, or a wedge-shape, between two neighboring

FIG. 109.

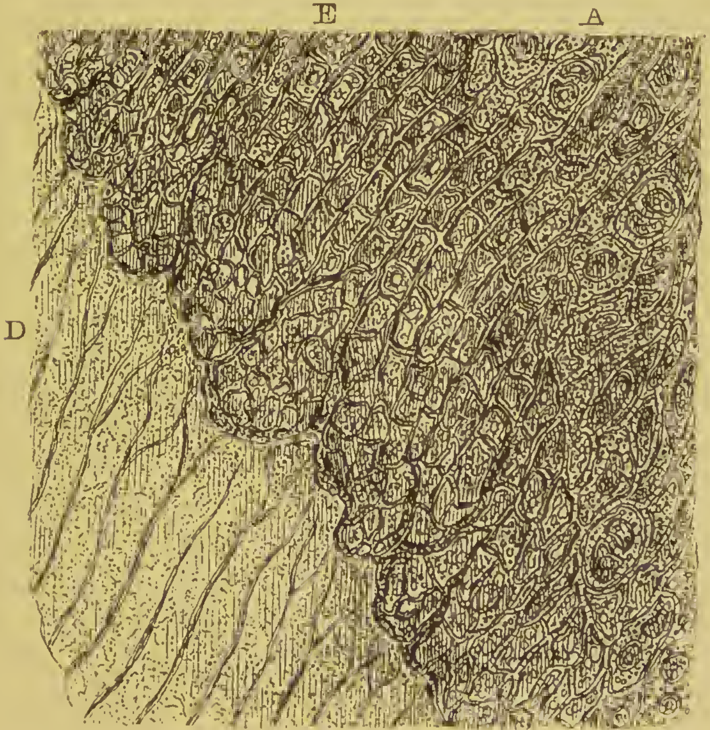


SEGMENT NEAR THE FOLD OF THE ENAMEL-ORGAN, CORRESPONDING TO THE NECK OF THE FUTURE TOOTH OF A HUMAN FŒTUS OF THE SEVENTH MONTH.

PP, papilla; *S*, stellate reticulum in an early stage of development; *M*, medullary corpuscles in a nearly uniform distribution, becoming elongated higher up, and arranged in rows; *A*, ameloblasts at an early stage of formation, composed of medullary corpuscles; *P*, protoplasmic bodies producing the outermost portion of the enamel-organ. Magnified 1200 diameters.

funnel-shaped ameloblasts (see Fig. 106, *A*). All ameloblasts are interconnected by delicate conical threads traversing the light interstices between them. Their layer is easily distinguished from the stellate reticulum by the intermediate layer, which is composed of spindles and fibers. From their bases delicate short offshoots often emanate (Tomes's processes), which, however, do not exhibit any regular arrangement. Where the layer of ameloblasts is detached from the surface of the papilla, similar short processes emanate from the surface of the latter, and it is obvious that all these fine offshoots serve for an interconnection between the ameloblasts and the medullary corpuscles of the papilla.

FIG. 110.



FIRST-FORMED ENAMEL OF A HUMAN FŒTUS OF SIX MONTHS.

D, dentine bounded toward the enamel by bay-like excavations; *E*, enamel composed of prismatic pieces; *A*, rows of medullary corpuscles sprung from previous ameloblasts. Magnified 1000 diameters.

Still nearer the summit of the crown the ameloblasts once more lose their character, and once more break up into medullary corpuscles, more or less retaining their row-like arrangement. We observe that the medullary corpuscles which lie nearest to the already-formed dentine are finely granular, whereas the rows some distance above are coarsely granular or homogeneous. These finely-granular medullary corpuscles are at last infiltrated with lime-salts, and thus is produced the enamel proper. (Fig. 110.)

The first trace of enamel, as is well known, appears about the sixth month of intra-uterine life, at a period when a certain amount of dentine has already been formed. The outer surface of the dentine exhibits bay-like excavations, in which we often observe a flat layer of a finely-granular protoplasm, analogous to that found in the teeth of adults. Above this layer we see prismatic pieces of calcified basis-substance irregularly distributed, since the enamel-prisms, as a rule, do not reach the surface of the dentine, but are replaced by a homogeneous (Tomes's granular) layer. Yet above this the enamel-prisms are easily recognizable, and appear to be composed of more or less regular square pieces. We can see a deposition of lime-salts along the borders of the prisms, while their central parts often exhibit one large nucleus, or several coarse granules. The interstices between the rows of these square pieces frequently exhibit delicate fibrillæ, the enamel-fibers, which are in connection with broader protoplasmic tracts, lying in the boundary between the enamel and the dentine. These enamel-fibers send branches through the transverse interstices of the square pieces. Everywhere delicate offshoots are seen, indicating that the living matter of the previous medullary corpuscles is preserved, even after their infiltration with lime-salts.

In the eighth and ninth months of fœtal life, both the enamel and the dentine form solid caps, corresponding to the summit of the crown of the tooth, and the one is superimposed upon the other. In decalcified specimens of these tissues, when they have been stained with carmin or chloride of gold, we observe a striking analogy in the structure of the enamel to that of the dentine. With a magnifying power of 500 diameters, it is difficult to differentiate between dentine and enamel. The fibers in the canaliculi of the dentine closely resemble those of the interstices between the enamel-rods. Even the highest powers of the microscope exhibit a close resemblance of both tissues, more especially after the lime-salts have been completely removed by means of reagents.

Let us now ask the question, What is the ultimate fate of the epithelial cord of the enamel-organ?

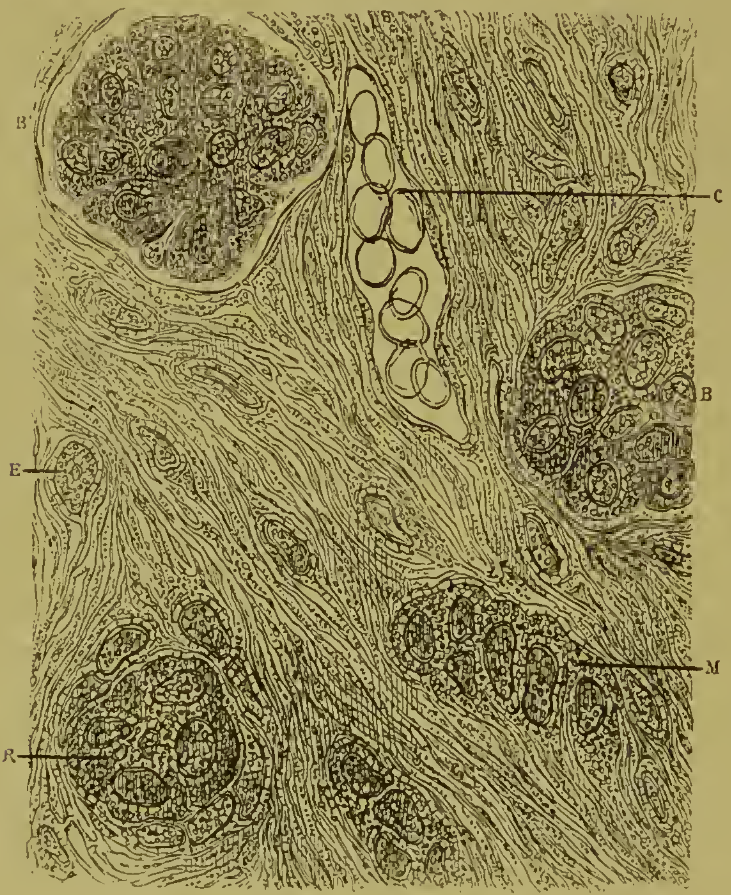
In the earliest stage of its development we meet with numerous lateral offshoots and sprouts, which, preceding their ultimate disappearance, are visible in the shape of medullary corpuscles. The destiny of the cord is obviously to produce the enamel-organ for the formation of the enamel. This process is accomplished with the fifth month of intra-uterine life. In the latter part of the fourth, and in the fifth month, the original epithelial cord undergoes peculiar changes, which have attracted the attention of many previous observers. The main change consists in the breaking up of the epithelial cord into innumerable clusters of a more or less markedly epithelial structure, between which fibrous connective tissue has appeared, completely isolating the clusters. Changes of this description are best seen in horizontal sections of the jaws. (See Fig. 107.)

With low powers of the microscope, we observe a large number of clusters which are distinctly marked in specimens preserved in chromic-acid solution. They have a brownish color, and may be either sharply outlined or more or less blended with the adjacent connective tissue. Many of these clusters hold concentrically-arranged epithelial nests, and, judged by their size and shape, they must have originated from a very active new growth of epithelium, which is indicated also by a number of buds sprouting from the original clusters. The buds have been pushed apart by fibrous connective tissue, since many of them appear entirely isolated, and as if imbedded in the fibrous connective tissue. Higher powers of the microscope reveal the fact that the process of dissolution of the original epithelial cord is identical with that of the dissolution of the external epithelium, the only difference being that in the latter process numerous newly-formed blood-vessels participate, whereas in the breaking up of the epithelial cord the new formation of blood-corpuscles and blood-vessels is not very conspicuous. (See Fig. 111.)

The smallest isolated clusters, still recognizable by their brownish color, only show traces of a division into epithelia through an intervening cement-substance. Most of them represent protoplasmic masses, with nuclei of varying size, interspersed at more or less regular intervals. Such clusters are often found surrounded by an almost homogeneous layer of a so-called basement-membrane. In the next stage, the cluster splits up into medullary corpuscles at its periphery, whereby its size is considerably diminished, and the basement-membrane lost. Ultimately the multinuclear protoplasmic mass, or the medullary corpuscles, split up into delicate spindles, which become infiltrated with basis-substance, thereby assuming the characteristic features of fibrous connective tissue. Sometimes we meet with single brownish corpuscles imbedded in fibrous connective tissue, and in size surpassing the nuclei of the latter. Such formations are possibly the last remnants of previous epithelia, that have escaped transformation into connective tissue.

The ultimate fate, then, of the epithelial cord of the enamel-organ is the same as that of the external epithelium, the cord being partly transformed into connective tissue. The further the development of the enamel and the enamel-organ proceeds, the less is visible of the original epithelial cord, although small epithelial clusters may be recognizable even in the sixth and seventh months of fœtal life.

Fig. 111.

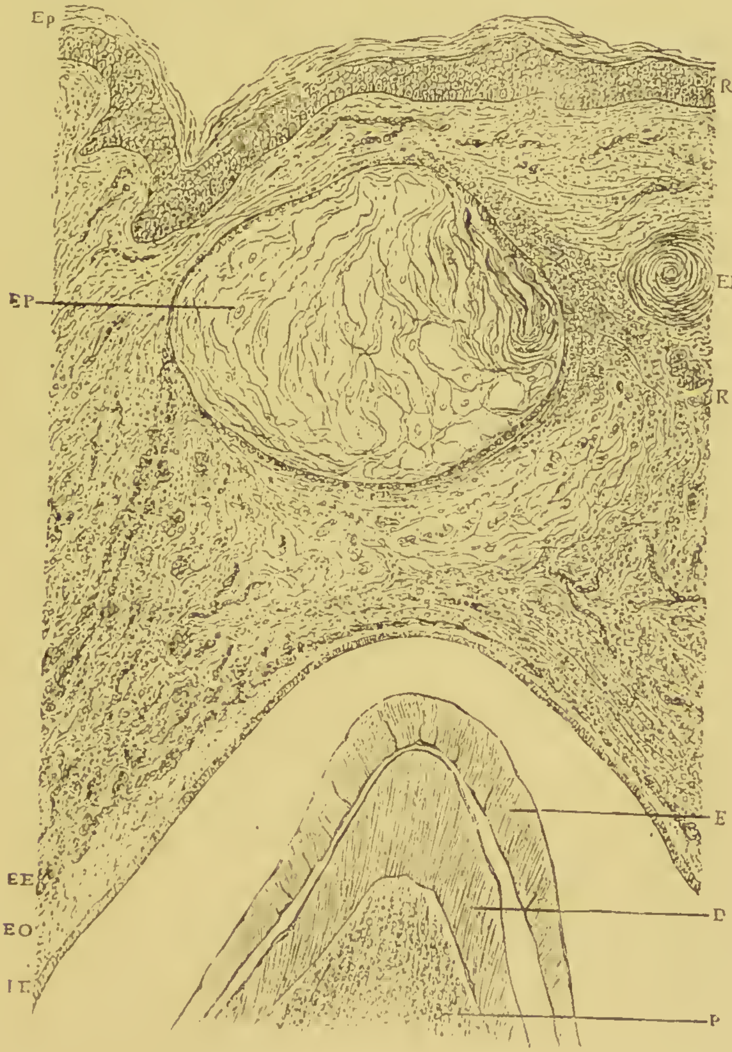


Dissolution of the Epithelial Cord of Enamel-Organ of a Human Fœtus Five Months Old. Horizontal Section.

C, capillary blood-vessel holding red blood-corpuscles; *B*, *B*, multinuclear protoplasmic masses arisen from the original epithelial buds; *R*, remnants of previous epithelia partly transformed into medullary corpuscles; *E*, single protoplasmic body, probably epithelium; *M*, medullary corpuscles in transition to fibrous connective tissue. Magnified 800 diameters.

We have already alluded to the possibility that the epithelium present between the outer surface and the enamel serves as stored-up material for the increase of the enamel, a possibility assumable since at the time of birth this tissue has by no means attained the full thickness which we observe at the time of the eruption of the tooth, and since, also, on that part of the surface corresponding to the summit of the enamel there is no proper enamel-organ left for the further growth of enamel-tissue.

Fig. 112.



Tooth of a Human Fœtus Seven and a Half Months Old. Vertical Section.

P, papilla; *D*, dentine; *E*, enamel; *IE*, internal epithelium; *EO*, enamel-organ; *EE*, external epithelium; *R*, remnants of epithelial cord; *EN*, epithelial nest; *EP*, pit filled loosely with flat epithelia; *RM*, rete mucosum; *Ep*, horny layer of the oral mucosa. Magnified 50 diameters.

The epithelial cord does not, however, completely disappear toward the end of intra-uterine life. Near the surface of the oral mucosa we often meet with comparatively large spaces filled with loosely-arranged flat epithelia of the character of epidermal scales, as illustrated in Fig. 112.

Thus far we have been unable to trace the connection of such a large pit with the rete mucosum, or surface of the oral epithelium. But there can be no doubt as to the origin of the pits. They must have arisen from the original epithelial cord, since the epithelial cord of the permanent tooth may be traced from their periphery. The cord in our specimen is broadened at its distal end and surrounded by a small papilla corresponding in every respect to the developing temporary tooth in an embryo of about three and a half months. The epithelia filling the pit are arranged loosely, similar to those of the horny layer of the oral mucosa, and many of them hold glistening granules of what possibly is eleidin. The boundary of the pit is made up of a single row of cuboidal epithelia, which in some places may produce stratified hills and protrusions. The pit corresponds to the summit of the temporary tooth, and its destiny seems to be to prearrange the route for its eruption. Between the lower periphery of the pit and the upper boundary of the enamel-organ, or rather its external epithelium, the connective tissue is loose and approaches the myxomatous structure, containing very small groups of epithelium or medullary corpuscles sprung therefrom. Such clusters are especially conspicuous in the space between the epithelial cord of the permanent tooth and the external epithelium of the enamel-organ, where a large number of capillary blood-vessels is also visible.

Among the different animals in whose jaws we have examined the process of formation of the enamel, we may mention the following:

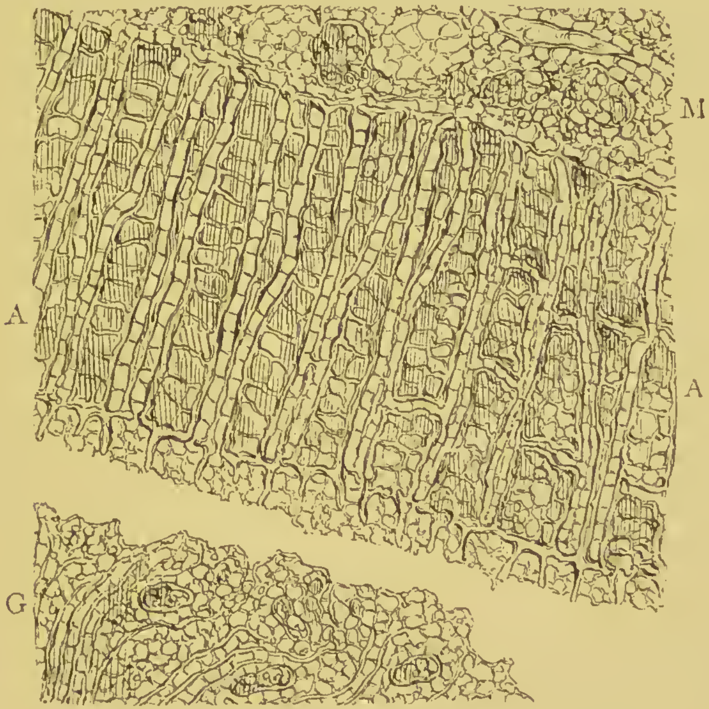
Kittens, at the time of birth, show all stages of the formation of teeth, and especially the breaking up of the inner epithelium into medullary, and afterward into myxomatous, tissue, which is easily traceable. All the details, however, correspond to those observed in human beings.

In a newly-born pup the formation of enamel was found to be, in all essential points, identical with its formation in man.

The fœtus of a pig affords an excellent example for the study of the formation of ameloblasts from medullary corpuscles.

(Fig. 113.) The ameloblasts are arranged with great regularity, being alternately wedge-shaped in opposite directions. Their reticulum is very wide, and the horizontal threads traversing the interstices are quite plain. From their bases arise a varying number of offshoots, directed toward a peculiar tissue which occupies the space between the ameloblasts and the already-formed dentine. This tissue appears granular with low powers of the microscope. High powers, however, plainly reveal a reticular structure, traversed by delicate fibrillæ in connection with the reticulum. The presence of nuclei in this tissue indicates its origin from medullary corpuscles.

FIG. 113.

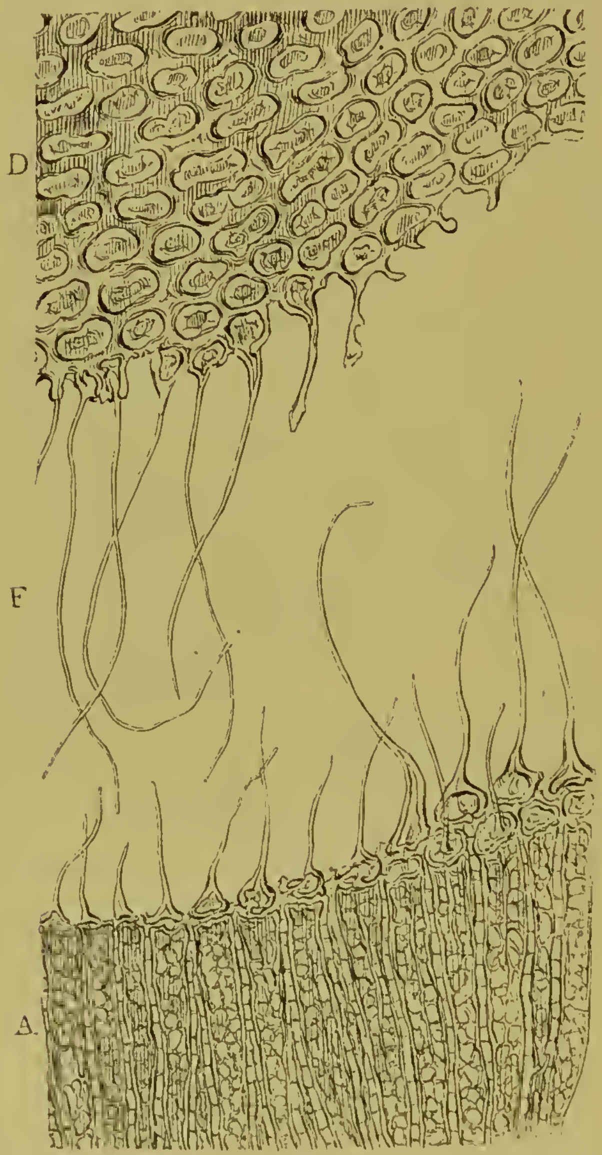


AMELOBLASTS OF A PIG'S FŒTUS, ABOUT TEN CENTIMETERS LONG, BEFORE THE FORMATION OF ENAMEL.

M, Myxomatous enamel-organ; *A*, *A*, rows of ameloblasts of a markedly reticular structure; *G*, granular layer between the dentine and the ameloblasts. Magnified 1200 diameters.

The fœtus of a lamb, about ten centimeters long, shows a large layer of ameloblasts. (Fig. 114.) In places where the ameloblasts lie close to the dentine, no fibrillæ are seen, but where the layer of ameloblasts is detached, a large number of fibrillæ appear, evidently belonging to the dentine. This is less calcified and takes up a deep carmin stain, contrary to the fully-calcified central portion of the dentine, that usually remains unstained. Here is wedged in between the dentine and the ameloblasts a layer found only as belonging to the sheep. The ameloblasts break up into medullary corpuscles before forming enamel, in the same manner as in human beings and other animals that we have examined.

FIG. 114.



SECTION OF A TOOTH OF A SHEEP'S FŒTUS, ABOUT TEN CENTIMETERS LONG.

D, dentine in transverse section; *F*, fibers drawn out from the non-calcified portion of the dentine; *A*, layer of ameloblasts partly in connection with the dentine. Magnified 1200 diameters.

Valuable researches in the study of the development of the enamel have been published by Frank Abbott,* as follows:

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* "Growth of Enamel." *Dental Cosmos*, 1889.

"A. Kölliker, in his 'Handbook of Histology of Man' (1852), speaks of development of enamel in the following terms: 'The development of the dental substances has always been considered a rather difficult topic. The relations are the simplest in the enamel, where not the slightest doubt prevails that the enamel-cells, by a complete calcification, become transformed into enamel-fibers (enamel-rods). As soon as a small portion of the cells, without any preliminary deposition of lime-particles, is being ossified, we recognize a small lamella of enamel over the somewhat larger dentine cap, which has also recently originated. The deposition of lime proceeds in the cells from within outward till they have at last been transformed into enamel-fibers and simultaneously transgress on new cells, by which means the layer of enamel is broadened. While this is going on, the enamel-membrane has not disappeared at the place where the ossification has started. On the contrary, we find this membrane always of the same breadth so long as the deposition of the enamel lasts, which proves that the ossified portion of the membrane is continuously being replaced by an additional mass. Apparently this is done, not by the production of new cells, but by a continual outgrowth of the original ones. The enamel-organ (stellate reticulum) is certainly of great importance in the building up of enamel, and owing to its richness in albumen and a gelatinous mass in its meshes is, so to speak, a pantry from which the enamel-membrane derives the material for its growth, being at some distance from the blood-vessels. In fact, we see this spongy tissue losing in its bulk during the development of enamel, and finally disappearing when the formation of enamel is completed.'

"I will here add that to Kölliker the enamel-membrane means a layer of epithelia. He describes the enamel-organ as being made up of anastomosing star-shaped cells, or a reticular connective tissue, which in its meshes contains a large amount of albumen and a liquid rich in mucus. The same author, in his work on the 'History of Development of Man and Higher Animals,' in 1879, claims that the stellate reticulum of the enamel-organ in appearance is identical with connective tissue, but is really nothing but a peculiarly transformed epithelium. Kölliker, therefore, in 1852, held an opinion that we consider to-day the correct one, which he very materially modified, almost to the point of abandonment altogether, years later.

This author was the first to announce that the theory of exclusiveness is not tenable, in the process of development from the three original embryonal layers, the 'ectoderm,' the 'mesoderm,' and the 'entoderm,' or, using Balfour's terminology, the 'epiblast,' the 'mesoblast,' and the 'hypoblast'; and still he narrows his views to an almost incredible degree, in the chapter upon development of enamel.

"John Tomes, in his 'Dental Physiology and Surgery' (London, 1848; Philadelphia, 1853), gives wonderfully accurate drawings of what he calls enamel-pulp, or columnar tissue, now known as ameloblasts. On page 102 he explains the development of enamel-rods or fibers in the following words: 'The cells being formed in lines, eventually become confluent; the points of union being sometimes transverse, and at other times oblique. At this stage the earthy elements are received, and the lines of union between the component cells of the fibers become less distinct, and are eventually lost, leaving a continuous fiber. The nuclei, from the first very small, are altogether lost in the formation of the fibers, or exist as very fine tubes passing through the length of each.'

"On page 104 we read: 'To the best of my belief the transverse striæ are due to the alternate dilatation and contraction of the fibers,—each dilatation corresponding to the center of a formative cell, and each contraction to the junction of two cells.'

"From these quotations it becomes evident that John Tomes was a most careful observer. Even at that early date, with the limited powers of his microscope, he conceived the full truth when he stated 'that each enamel-rod is the result of a juxtaposition of formative cells, between which are left the striæ.' He considers the formative cells as the recipients of the calcareous matter in exactly the same way as we see it to-day.

"F. Waldeyer, in his 'Handbook of Histology,' edited by Stricker, in Leipzig, 1869, page 347, describes the formation of enamel in the following manner: 'The formation of enamel is done exclusively by the enamel-epithelium, since the enamel-prisms are the result of a direct calcification of its long cylindrical cells. The boundary of petrifaction on the cells is by no means linear, but extends downward to an irregular depth,—a fact which likewise is not in favor of the view that a secretion of the enamel-cells is being calcified. After treatment of young enamel with dilute acids, the enamel-prisms slightly swell and resume entirely the form of the previous cylindrical cells. The disappearance of the nuclei, in the process of the calcification of the cells, is of so common occurrence that their absence in the enamel cannot cause any wonder. Enamel, therefore, is to be considered as the petrified dental epithelium.'

"This author explains the formation of the stellate reticulum by a transformation of the epithelia, and considers its gelatin of a merely mechanical importance, since it keeps an open space for the growing tooth.

"John and Charles S. Tomes, in their 'System of Dental Surgery' (London, 1873, page 253) say, 'The conclusions respecting the development of enamel which are most in accordance with appearances observed are these: The columns of the enamel-organ (enamel-cells, internal epithelium of the enamel-organ) are subservient to the development of the enamel-prisms, into which they by calcification become actually converted. This conversion goes on in the following method: The proximal end of the cell undergoes some chemical change preparatory to calcification, and is subsequently calcified; but this calcification does not go on uniformly throughout its whole thickness, but proceeds from its periphery toward its interior, the central portion of the cell thus being calcified later than the external portion, which lies at the same level. At the same time that calcification is proceeding inward, in each individual cell, it has united the contiguous cells to each other. The calcification of the central portions of the enamel-fibers does not keep pace with that of their exteriors, nor even in fully-completed enamel does it attain to precisely the same characters. In the progress of calcification the nuclei of the enamel-cells disappear, and it is probable, as is believed by Waldeyer, that the internal epithelium of the enamel is reunited by the cells of the stratum intermedium as it becomes itself used up by advancing calcification, converting it into enamel-fibers.'

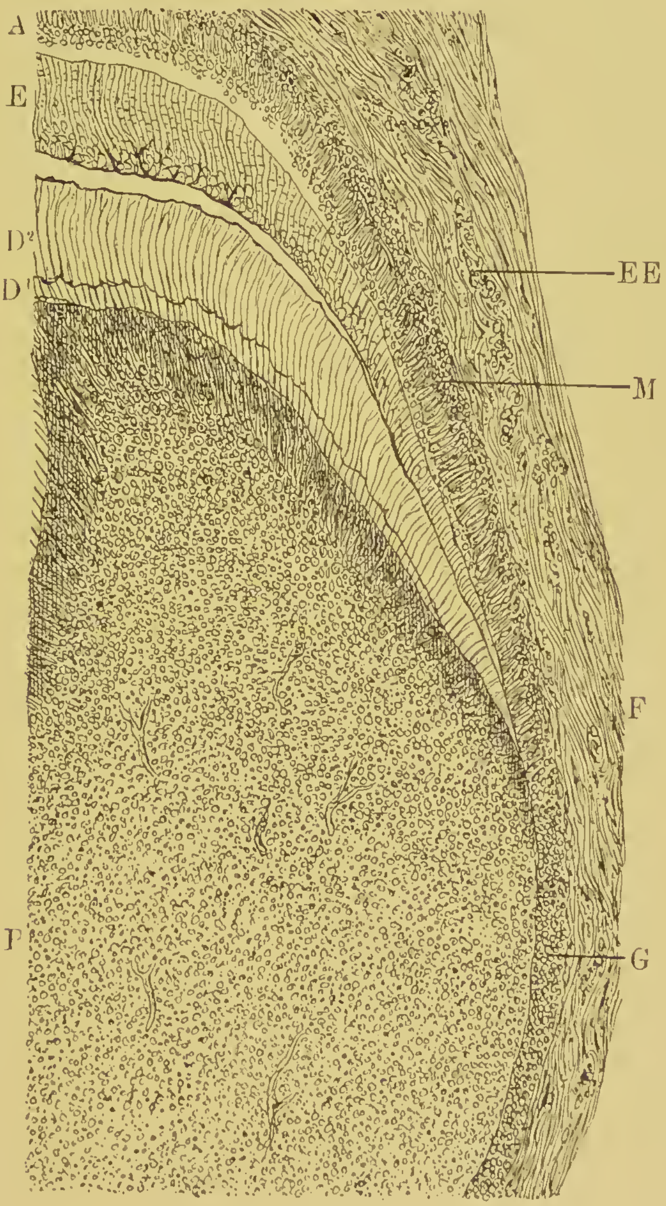
"These authors give credit to Kölliker as the originator of the idea that the enamel-cells do not undergo direct conversion into enamel-fibers, but that the enamel is, as it were, shot out from their ends,—that is, it is a secretion from them, not a deposition of lime-salts into their own substance. Our quotations from Kölliker's original German work, issued in Leipzig in 1852, plainly show that he at that time believed fully in the conversion theory. Since the Tomeses quote from the fifth German edition of Kölliker's histology, issued in 1867, it is obvious that he has changed his views, much, in my judgment, to his own disadvantage.

"The views announced by C. Heitzmann and C. F. W. Bödecker are in harmony with my own observations, and furnish the foundation of what I have to add, in the way of a more comprehensive idea of the building process of enamel, than has heretofore been advanced.

"Fig. 115 gives an illustration of the views just alluded to. The figure, it must be emphasized, is not diagrammatic, but copied with the utmost care from a specimen of a human fœtus six months old, the period at which enamel begins to appear. The different layers, it will be observed, appear separated from one another. This is usually the case even in the most carefully prepared specimens, owing to slight mechanical injury in cutting, and to shrinkage of the soft parts; the relations, however, are absolutely correct in this drawing.

"After the epithelial peg has grown into the depth of connective tissue of the oral mucosa, in the twelfth week of embryonal development, the distal end of this peg becomes club-shaped, and then appears the first trace of medullary tissue, which two weeks later plainly shows the stellate reticulum. The club at this period assumes a cup-shape, whose concave surface is lined by the internal epithelium, while the outer surface is made up of the so-called external epithelium, which is in uninterrupted continuity with the internal epithelium at the most prominent border of the cup. If we examine the lower edge of the cup of the enamel-organ at about the sixteenth week of embryonal life, we observe a peculiar change in the columnar bodies of the internal epithelium, which consists in the appearance, in a more or less row-like arrangement, of highly-glistening globular bodies, replacing the previous columnar epithelia. These bodies are either solid or slightly vacuoled, and are formations of living matter such as we are accustomed to look upon as medullary, embryonal, or indifferent corpuscles in their earliest stage of appearance. Obviously these glistening globules have originated from the reticulum of living matter of the columnar epithelia themselves. We feel justified in this conclusion from the fact that we can trace, step by step, the growth of these glistening granules up to the formation of glistening lumps, such as we have termed medullary corpuscles. The more the cup of the enamel-organ is enlarged,

FIG. 115.



TOOTH OF HUMAN FOETUS, SIX MONTHS.

P, papilla; D^1, non-calcified dentine; D^2, calcified dentine; *E*, enamel; *A*, row of ameloblasts; *M*, medullary corpuscles at the peripheral portion of ameloblasts; *G*, globular corpuscles from which ameloblasts develop; *EE*, buds of external epithelium; *F*, follicle, made up of fibrous connective tissue. Magnified 100 diameters.

the more conspicuous becomes the transmutation of the previous internal epithelium into glistening lumps; so much so that toward the end of the fifth month of fœtal life the original columnar epithelium at the concave portion of the cup has entirely disappeared. In its stead begin to show, first at the deeper portion of the cup, and closely resembling columnar epithelia, other bodies, now known as ameloblasts, or enamel-formers.

"From this description it seems evident that all previous observers—be it said with due respect to their judgment—have been in error in the assumption that the columnar epithelia of the internal wall of the cup were identical with the ameloblasts. All these observers have overlooked the intermediate stage of the glistening medullary lumps. In Fig. 115 these lumps are marked *G*. They are traceable down to the neck of the papilla, therefrom to the point of recurvation of the previous internal into the previous external epithelium. The lumps, I wish to repeat, are extremely glossy, with a high degree of refraction. They are arranged, at first irregularly, in a layer of considerable breadth, and higher up in rows, and by their coalescence and prolongation give rise to small columns, the ameloblasts. These are seen up to the end of the fifth month of fœtal development at the deepest concavity of the cup and its lateral walls down to varying depths, and closely attached to the now-forming dentinal cap. The odontoblasts grow smaller toward the thin extremity of the dentinal cap, and below its end they appear as blunt and short columns; while, close above, the ameloblasts make their appearance, being traceable all around the outer periphery of the dentinal cap.

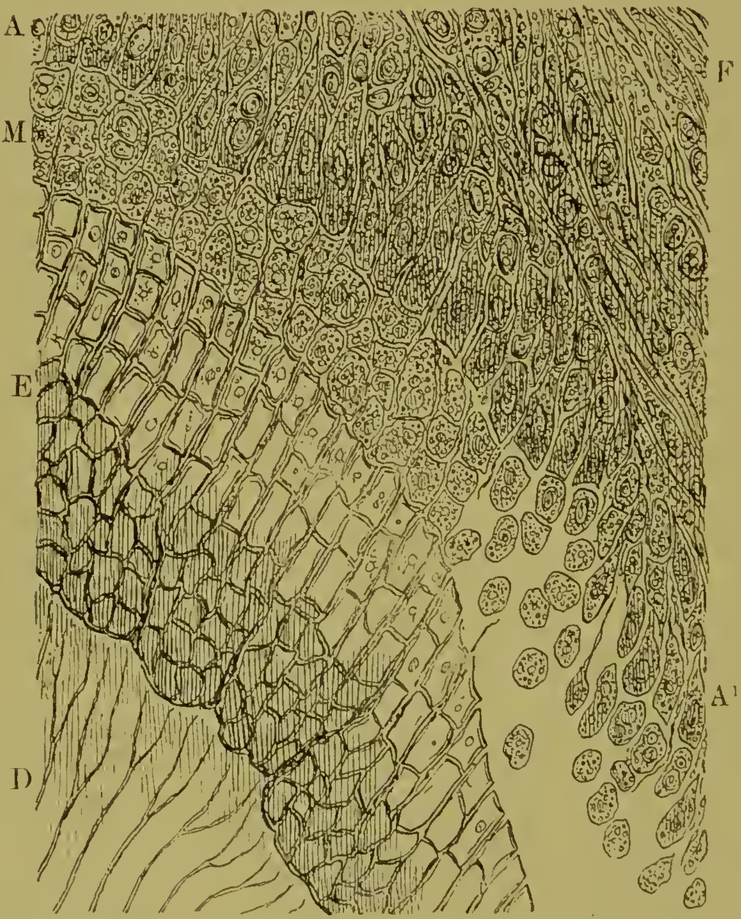
"In the sixth month of fœtal life, as is well known, the enamel-cap begins to show; first at the summit of the dentinal cap, where it gains its greatest breadth, gradually becoming thinner toward the sloping sides, and, as a whole, a trifle thinner and shorter than the dentinal cap.

"If we now examine the ameloblasts close above the already-formed enamel, we shall observe finely-granular bodies, arranged in a row, between the enamel and ameloblasts. These are best seen in specimens where the hardening and cutting procedures have not caused a detachment of the soft tissues from the hard, —*i.e.*, the enamel-organ from the calcified enamel. It is seldom that this is accomplished; but a few of such perfect specimens are in Bödecker's collection, which by his kind permission I have used for my studies and these drawings. Even though a slight detachment has occurred, the enamel-organ still remains intact, and the finely-granular corpuscles at the proximal ends of the ameloblasts remain visible.

"What are these finely-granular bodies? Heitzmann and Bödecker claim that they are medullary corpuscles, holding small and indistinct or no nuclei, and only a very small amount of living matter, which accounts for their finely-granular appearance with low powers of the microscope. They further claim that these corpuscles, or the liquids contained in their reticulum, become solidified into basis-substance, and immediately infiltrated with lime-salts. They claim also that the enamel-rods are built up of rows of such calcified or 'petrified' medullary corpuscles, the successive arrangement of which into rows causes the more or less regular appearance of the transverse striæ of Retzius; whereas, between the rows, longitudinal interstices will remain, filled, perhaps, with a small amount of cement-substance, differing in its chemical constitution from the basis-substance of the rods proper, and in its interior holding extremely delicate fibrillæ (Bödecker's enamel-fibers) which branch into the transverse striæ. Being satisfied that the views of these gentlemen are correct, I will simply add a new feature, to make those views more symmetrical,—and, as it occurs to me, it is a feature of considerable importance,—viz. the changes that take place in the ameloblasts during the process of the formation of enamel. (Fig. 116.)

"The ameloblasts, as just stated, split up into rows of finely-granular medullary corpuscles, and consequently are reduced considerably in their size. In fact, it is difficult to find full-sized ameloblasts at the summit of the enamel-cap, where the production of enamel is most active, the same as it is impossible to find full-sized odontoblasts at the summit of the papilla, where the formation of dentine is most active. The mutilated ameloblasts in this situation still exhibit nuclei, although their forms are odd,—mostly cut or broken, with offshoots running upward and laterally toward the stratum intermedium. At the same time, peculiar glistening, homogeneous lumps and irregular wedge-shaped nucleated bodies appear between the offshoots of the ameloblasts; not as regular, however, as the original medullary corpuscles were, from which the ameloblasts originally developed. All these indifferent bodies must have arisen from the living material stored up in the stratum intermedium, close above the row of ameloblasts. By their occasional row-like arrangement I am led to the conclusion that they serve for a *restitution* or *rebuilding* of the ameloblasts (which at their proximal ends have split up into *enamel-formers*), and thus serve to establish a continuity of the ameloblasts, and, in turn, of the enamel-rods, throughout the whole thickness of the enamel. In a previous article I have endeavored to show that odontoblasts, being split up at their distal ends into medullary corpuscles, enter directly into the formation of the basis-substance

Fig. 116.



First-Formed Enamel of Human Fœtus, Six Months.

D, dentine: *E*, enamel toward the dentine, made up of irregular calcified fields, toward the periphery of prisms with transverse interruptions; *M*, medullary corpuscles, finely granular, from which the enamel-prisms are formed; *A*, ameloblasts, toward the enamel breaking up into medullary corpuscles, toward the periphery rebuilt by such corpuscles; A^1, irregular ameloblasts torn from their connection with enamel; *F*, fibrous connective tissue, changing to medullary tissue. Magnified 800 diameters.

of dentine, while at the same time, continually superadded to the proximal ends of the odontoblasts, are medullary corpuscles derived from the living matter of the papilla. Thus the continuity of the odontoblasts and dentine is established, stratification of the dentine being the exception. I now assert a similar procedure for the ameloblasts, in a reverse direction, owing to the centrifugal direction of enamel-growth. *The ameloblasts being broken up at their proximal ends into medullary corpuscles, which are directly transformed into blocks of enamel-rods, are superadded to at their distal or peripheral ends by medullary corpuscles derived from the stratum intermedium.* Normal enamel is non-stratified; its rods or prisms run a wavy course, as a rule uninterruptedly from near the dentine to the cuticular (Nasmyth's) membrane.

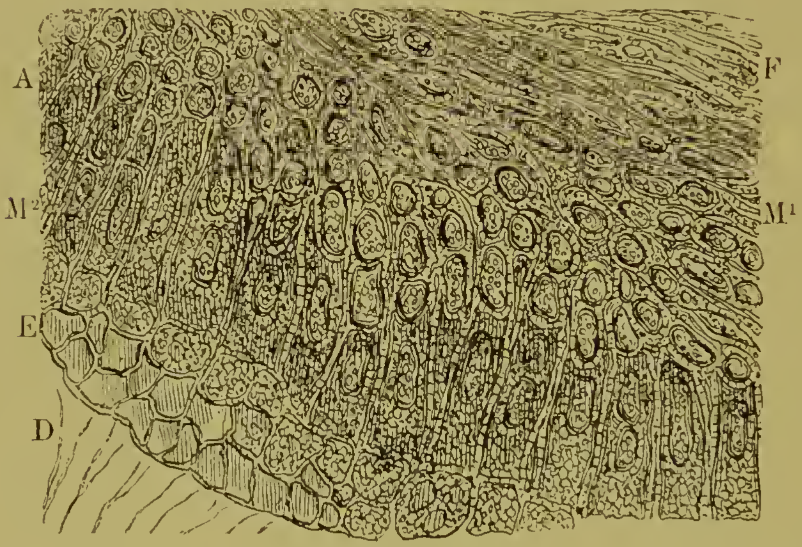
"Neither the structure nor the development of this tissue is to me explicable on the ground of the cell theory, which suggests that each cell is an individual, and but exceptionally in connection with its neighbor. To us, a cell is a lump of protoplasm, in which the living matter is stored up in different shapes. The glistening globules of small size, having arisen from the protoplasm of the original columnar epithelia of the enamel-organ, represent a juvenile condition of living matter in its most compact aggregation.

"The medullary corpuscles, sprung from the ameloblasts, show only a delicate reticulum of living matter, being ready for immediate transformation into basis-substance and calcification. Between these extreme stages stand the ameloblasts, with their vesicular nuclei, and a markedly heavy reticulum of living matter in their interior. The indifferent corpuscles, serving to supply additions to the ameloblasts, exhibit all intermediate stages between small, globular, glossy and compact globules up to distinctly-nucleated protoplasmic lumps. Whatever the size and shape of such lumps may be, they are invariably connected with one another by means of delicate offshoots, which vary greatly in thickness and in their course. Each ameloblast sends offshoots toward the dentine in great numbers, known as Tomes's processes. They also run upward toward the intermediate layer, and laterally for the immediate union of neighboring ameloblasts. (See Fig. 117.)

"Broad and clumsy offshoots, such as depicted by Tomes and Waldeyer, are visible only upon torn and teased ameloblasts. So long as these bodies are *in situ*, the offshoots are always delicate, and visible with higher powers of the microscope only,—*i.e.*, from 800 to 1000 diameters. By the splitting up of the ameloblasts in a longitudinal direction, wedge-shaped pieces arise between funnel-shaped or square bodies. By the coalescence of the lateral offshoots in a longitudinal direction, delicate fibrillæ originate between the ameloblasts, known as Bödecker's enamel-fibers.

"When the formation of a tissue is going on, we conclude, from the great variety of forms of the protoplasmic bodies, that there is not for a moment rest either in the growth or in the new formation of living matter. Thus the proximal ends of the ameloblasts, through the intermediate stage of medullary corpuscles, are metamorphosed into the calcified basis-substance of the enamel-rods. The distal ends exhibit the stages through which the living matter passed before the original ameloblasts were formed. Still the question remains an open one, whether or not ameloblasts are an absolute requirement for the production of enamel after the formation of the rods has once begun. The rows of globular bodies as seen in Fig. 117, M^1, strongly

Fig. 117.



Ameloblasts beginning the formation of Enamel; from Human Fœtus, Six Months.

D, border of newly-formed dentine; *E*, first trace of forming enamel; *A*, row of ameloblasts; M^1, medullary corpuscles for restitution of ameloblasts; M^2, medullary corpuscles just previous to their infiltration with lime-salts; *F*, fibrous connective tissue, the so-called intermediate layer. Magnified 1000 diameters.

favor a negative answer to this query. Nothing but a transmutation of solid globular lumps of living matter into delicately-reticulated medullary corpuscles seems to be required for the building up of the minute blocks of enamel-rods, without the intermediate stage of ameloblasts. We must admit, however, that, to symmetry of construction, the part played by these bodies seems essential, although they vary greatly in size, even in the same tooth. We consider ameloblasts as merely provisional formations, by no means stable or unchangeable. This conclusion is the same as that we reached in regard to the significance of odontoblasts.

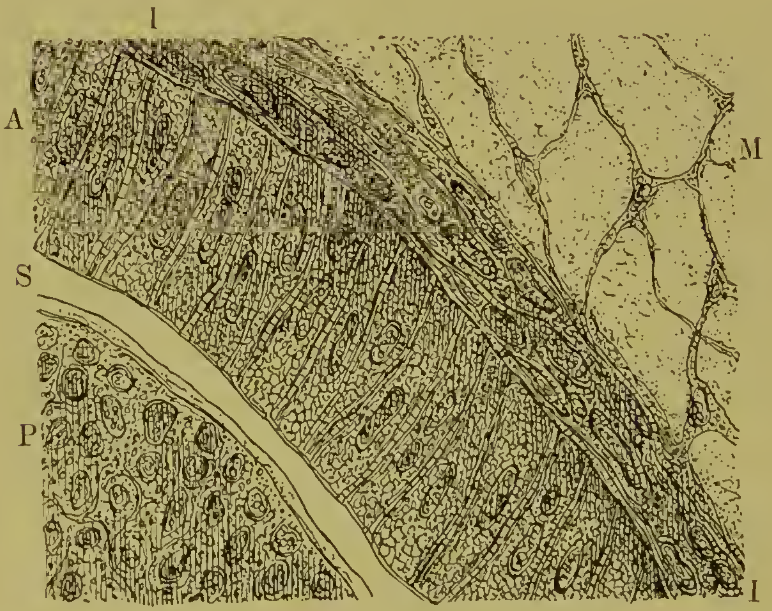
"Full development of ameloblasts into oblong or conical bodies—each containing one or two nuclei, sharply bordered by a delicate cuticular formation toward the papilla, and distinctly marked by the intermediate layer toward the enamel-organ—is never seen save under the condition of temporary rest, where the formation of enamel has not as yet started. (See Fig. 118.) As soon as the first trace of enamel is seen, the ameloblasts lose their regularity by being split up toward the dentine, and are superadded to from the intermediate layer.

"The first-appearing enamel is made up of irregular angular and glistening lumps, greatly varying in size. (See Figs. 116 and 117.) The first blocks of enamel-rods show compact edges and comparatively thin and translucent centers, in which even traces of the nuclei of the medullary corpuscles are to be seen. This plainly proves the correctness of the assertion of Tomes, that 'the enamel-rods are calcified from the periphery toward the center.' The irregularity of the first-formed calcified blocks also accounts for the fact that fissures and breaks are of such common occurrence in specimens of enamel, either ground or cut, at the border toward the dentine, as I have previously demonstrated in an article on the anomalies of enamel, such anomalies being most common in this situation.

"We now return to the enamel-organ, of which it is known that it begins to show at the end of the third month of intra-uterine life, by the appearance of medullary corpuscles between the internal and external epithelium. From the fourth month to the seventh or eighth the beautiful stellate reticulum known as the enamel-organ comes to view. Although Huxley and Kölliker have stated (in 1850–1852) that this is connective tissue, all modern writers, including Kölliker himself, insist that it is a peculiarly-modified epithelium. I contend that this reticulum is true myxomatous tissue, and the stratum intermedium true fibrous connective tissue. The first microscopist to describe and illustrate the intermediate layer was John Tomes, in 1848, in his work above quoted. This credit is usually given to Hannover, whose work appeared in 1856.

"As to the significance of the enamel-organ, I must take decided exception to the views of most modern writers,—viz, that it serves as a kind of protection cushion, or to preserve an open space for the tooth to grow into. In my opinion, the view first announced by Hertz in 1866 is the correct one,—*i.e.*, that 'the enamel-organ is stored-up material for the benefit of the growing enamel itself,' the same as is the intermediate layer.

Fig. 118.



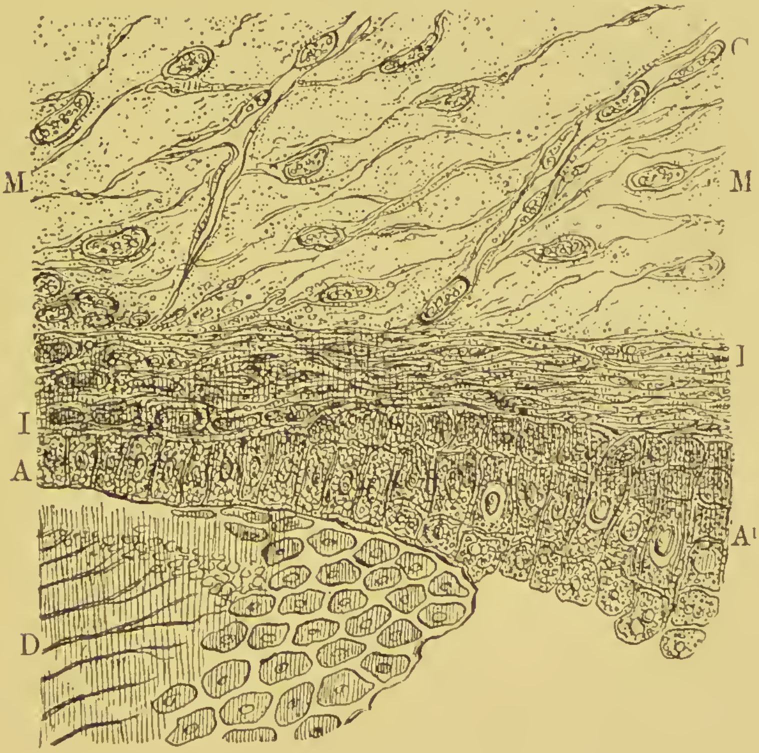
Ameloblasts at Rest; from Developing Tooth of Human Fœtus, Six Months.

A, row of ameloblasts; *I*, *I*, intermediate layer; *M*, myxomatous reticulum; *P*, papilla; *S*, so-called structureless membrane. Magnified 1000 diameters.

"One fact will strike every observer,—viz, that the enamel is seldom, if ever, perfectly symmetrical in the growing tooth, being on one side broader, to the extent of five or six times, than on the other; sometimes it is found only on one side of the developing tooth, while on the other nothing but delicate fibrous connective tissue is seen. From these facts we must conclude that the myxomatous form of this organ is by no means a characteristic or an absolute requirement.

"How can we explain the scantiness of this organ at the summit of the crown, where in full development the enamel has the greatest diameter? Can the original enamel-organ, even ever so broad, suffice for the production of the whole enamel? Is not the enamel-coat of a temporary tooth five, nay, ten times as broad as the original enamel-organ? All this strongly points to the conviction that the budding external epithelium, and even the primary epithelial peg, must furnish material for the building of enamel, no matter what the intermediate or subsequent changes of this tissue may be.

FIG. 119.



DEVELOPING TOOTH OF SHEEP'S FŒTUS, 10 CENTIMETERS LONG.

D, dentine in longitudinal and transverse sections; *A*, row of ameloblasts at rest; *A*¹, ameloblasts broken up into medullary tissue, preceding the formation of enamel; *I*, *I*, intermediate layer; *M*, *M*, myxomatous enamel-organ; *C*, capillary blood-vessels. Magnified 1000 diameters.

"In conclusion, I wish to say that I have studied the development of enamel in pigs and sheep, and have found the relations therein similar to those in the enamel of the human tooth. (See Fig. 119.) In the sheep's fœtus, ten centimeters long, the form-changes of the ameloblasts are especially pronounced, since shortly before the appearance of the enamel a splitting into medullary corpuscles takes place, for the production of enamel-rods; and at the same time, at their distal ends, new medullary corpuscles show themselves, evidently produced at the expense of the intermediate layer. Both the last-named layer and the blood-vessels in the myxomatous enamel-organ John Tomes observed and depicted as early as 1848,—an admirable instance of acute observation of lasting value."

CHAPTER XVI.

FAULTY DEVELOPMENT.

During the formation of the teeth, constitutional maladies in the possessor have an important influence upon the calcification of the dentine and the enamel. Any disturbances in the proper supply of lime-salts to the developing dental tissues may result in a malformation of the crown of the affected tooth, and cause interruptions in the process of calcification. The period at which defects in the dentine and enamel are most commonly produced, is after birth. We may also observe such anomalous formations of the crowns of teeth as the consequence of constitutional diseases of the mother during the time of pregnancy, or in other instances they may be inherited from the father or even grandfather. Upon the crowns of the affected teeth, which, at the time of the disease, are about to calcify, we notice transverse ridges, or grooves and pits, encircling the entire crowns of the teeth, such deformity being the more marked the longer and severer the disturbance has been. The color of these teeth usually is dark yellow, brown, or blue, although in some instances the enamel is found to be abnormally white and opaque. Occasionally, in spots, the crowns are devoid of enamel, and exceptionally we see teeth altogether destitute of enamel. In these cases the exposed dentine is of a dark-yellow or brownish color. The diseases which are believed to produce such deformities are syphilis, rhachitis, smallpox, scarlet fever, measles, and other inflammatory disturbances of the skin or of the mucous membrane of the alimentary tract, and more particularly of the oral cavity. Some writers, especially J. Hutchinson, have attributed such deformities of the dental tissues mainly to hereditary syphilis. At present, however, it is acknowledged that such defective formations may be produced by other diseases which temporarily arrest the process of calcification of the enamel and dentine. It is believed by J. Tomes* that deformities resulting from constitutional disturbances of the mother affect in the infant the crowns of the temporary teeth, which are found in such cases to be small, abnormal in shape, and with but a thin coating of enamel. This author also states that it has been observed that children, whose permanent teeth were marked by deformed enamel, have lost them early through caries, pericementitis, or periostitis. In these instances, it is possible that the defects of the permanent teeth are as much the cause of the pericementitis and the periostitis as the result of constitutional ailments of the mother.

Furthermore, such disturbances occur at a period when the enamel-organs of the permanent teeth are in their first stage of development. It is therefore inexplicable why these teeth should be marked by deformities, while the crowns of the temporary teeth, at that time in progress of calcification, are usually normal in appearance. The author has seen a girl about eight years of age, whose remaining temporary teeth were all marked by deformed enamel, while the permanent incisors and first permanent molars were possessed of a normal enamel. When the disease has been of a local character, it may occur that it has affected but one or a few teeth in one jaw only, while all the other teeth are normal; although, when the local ailment has extended over the mucous membrane of the whole mouth, all the teeth that are in process of calcification will be affected. By carefully studying the time when the crowns of the teeth calcify, we are enabled to judge at what year of life the child was ill. (See Fig. 120.) Thus, when the illness has occurred during its first year, we notice deformities only upon the cutting-edges of the permanent central incisors and the cusps of the first permanent molars; while the disease during the second year of life will mark the permanent central as well as the lateral incisors, and the first permanent molars. When the illness of the child happens during the third year, the deformity appears about in the middle line of the permanent centrals, and a little nearer the cutting-edge of the lateral incisors. The

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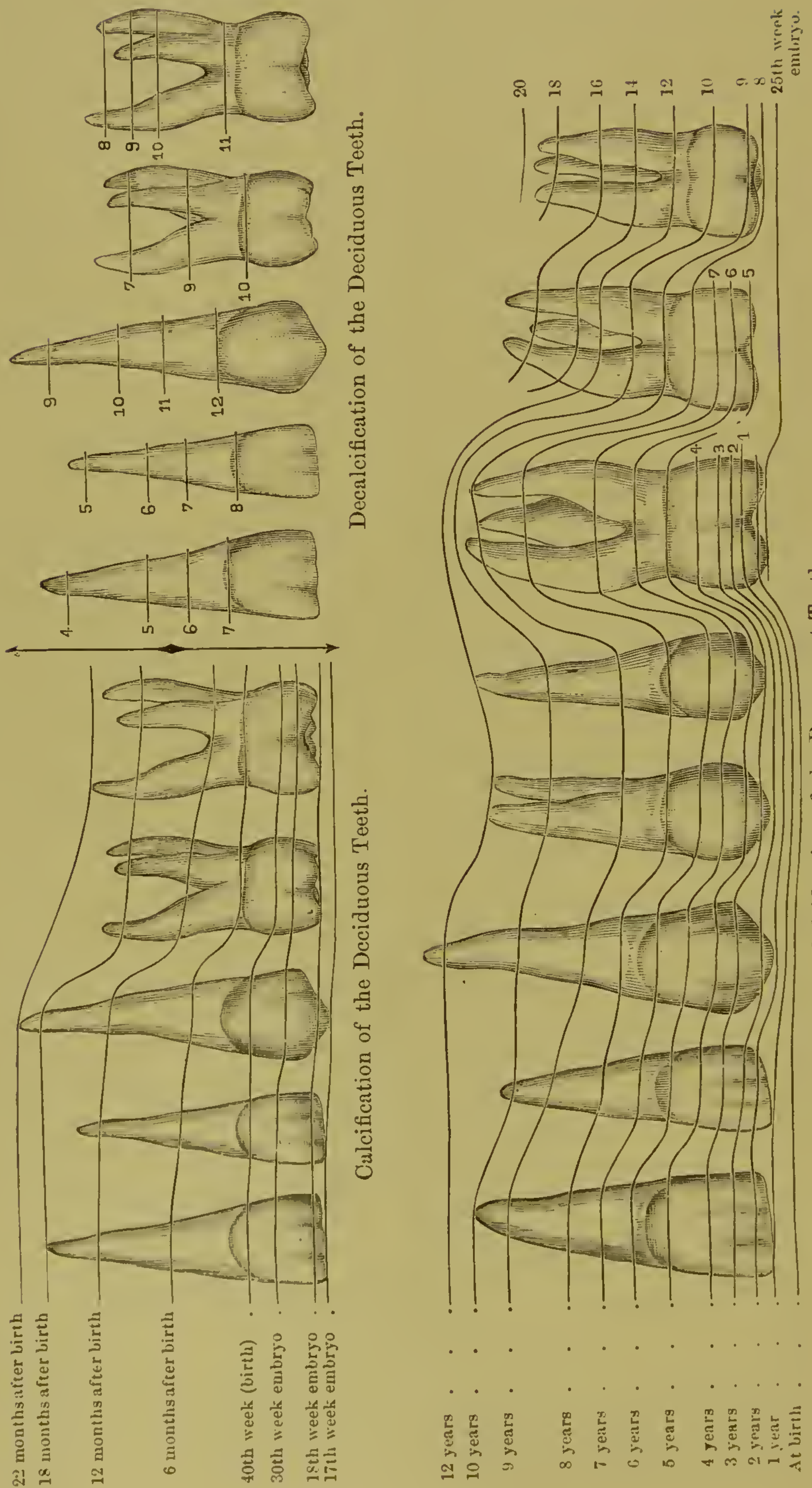
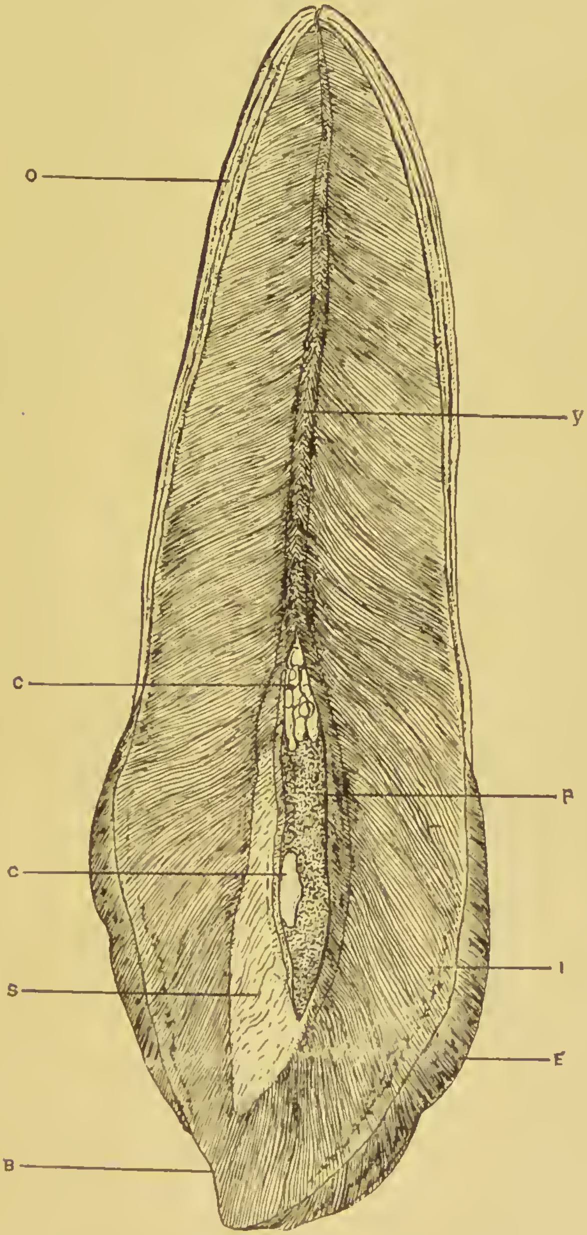
* "A System of Dental Surgery." Philadelphia, 1873.

Fig. 120. (After C. N. Peirce.)



buccal cusps of the bicuspids and cuspids may either escape injury or show a slight defect, but the first permanent molars usually are deformed in the same level with the central incisors. If a child has been seriously ill during the fourth year, we find

FIG. 121.



RIGHT UPPER PERMANENT CENTRAL INCISOR, MRS. K., FORTY-EIGHT YEARS OLD. GROUND.

B, dentine, lacking enamel; *S*, secondary dentine, corresponding to bare dentine; *E*, narrow layer of pigmented enamel; *I*, zone of interglobular spaces; *P*, pulp-tissue; *C*, *C*, calcareous deposits in the pulp-tissue; *V*, dentine in immediate vicinity of pulp-canal; *O*, narrow layer of osteoid cementum. Magnified 6 diameters.

the defective transverse line of the enamel nearer the neck of the permanent central incisors, at about the middle of the laterals, and, in the case of the cuspids and bicuspids, on the points of the cusps, while the first permanent molars are marked similarly as the central incisors,—*i.e.*, near the necks. Sometimes it occurs that children are attacked by chronic constitutional or local diseases immediately after birth, and lasting up to the third or fourth year of life. In such an instance we may notice that the greater portion of the crowns of the permanent central and lateral incisors, as well as the first permanent molars, present a crippled appearance.

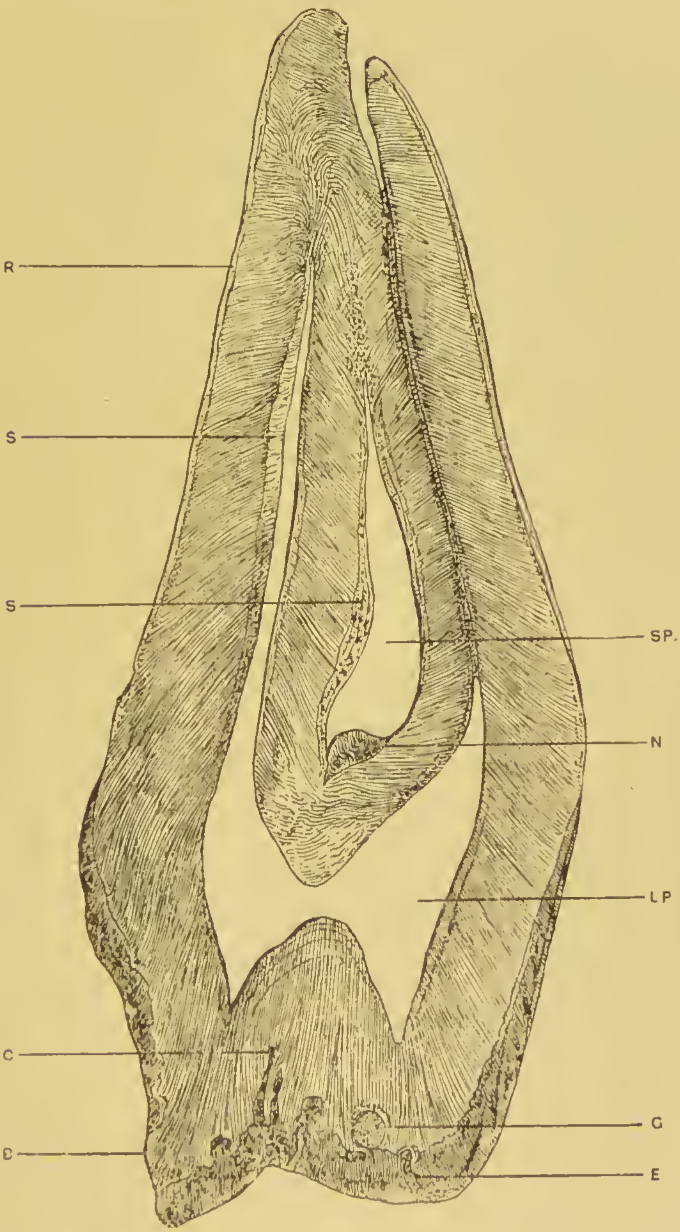
While the above-named maladies usually result in deformities of the crowns of the teeth, we occasionally meet with persons who in their early childhood have been seriously ill, but whose permanent teeth are possessed of normal enamel. Although it cannot be denied that some of these deformities are the result of constitutional ailments of the child, still the above facts to a great extent corroborate Abbott's statement, to the effect that faulty formations of the enamel are the result of local disturbances.

An instance of faulty development of the enamel is illustrated in Fig. 121. This represents the right upper permanent central incisor of a lady about forty-eight years of age, who knows of no disease of her mother or of her own childhood. The tooth became loose in consequence of chronic suppurative pericementitis, and was extracted.

The enamel is narrow and intensely pigmented. It is missing altogether in a circumscribed spot of the lingual surface of the tooth near the cutting-edge. The dentine shows a zone of interglobular spaces in the crown, more pronounced on the labial than on the lingual surface. Corresponding to the bare surface of the dentine there is a marked formation of secondary dentine, holding irregular and scanty canaliculi. The pulp is normal, and shows a number of calcareous deposits, especially at the beginning of the pulp-canal. The cementum is altogether of the osteoid type, and, although lamellated, is devoid of cement-corpuscles. The process of chronic pericementitis has not affected the cementum, which nowhere exhibits the bay-like excavations characteristic of cementitis.

An instance of traumatism of considerable interest is the tooth depicted in Fig. 122. It is a right upper permanent central incisor of a youth twelve years of age, removed on account of the disfigurement as well as the overcrowded condition of the dental arch, the teeth of which were otherwise normal. The mother of the boy has informed me that the child always has

Fig. 122.



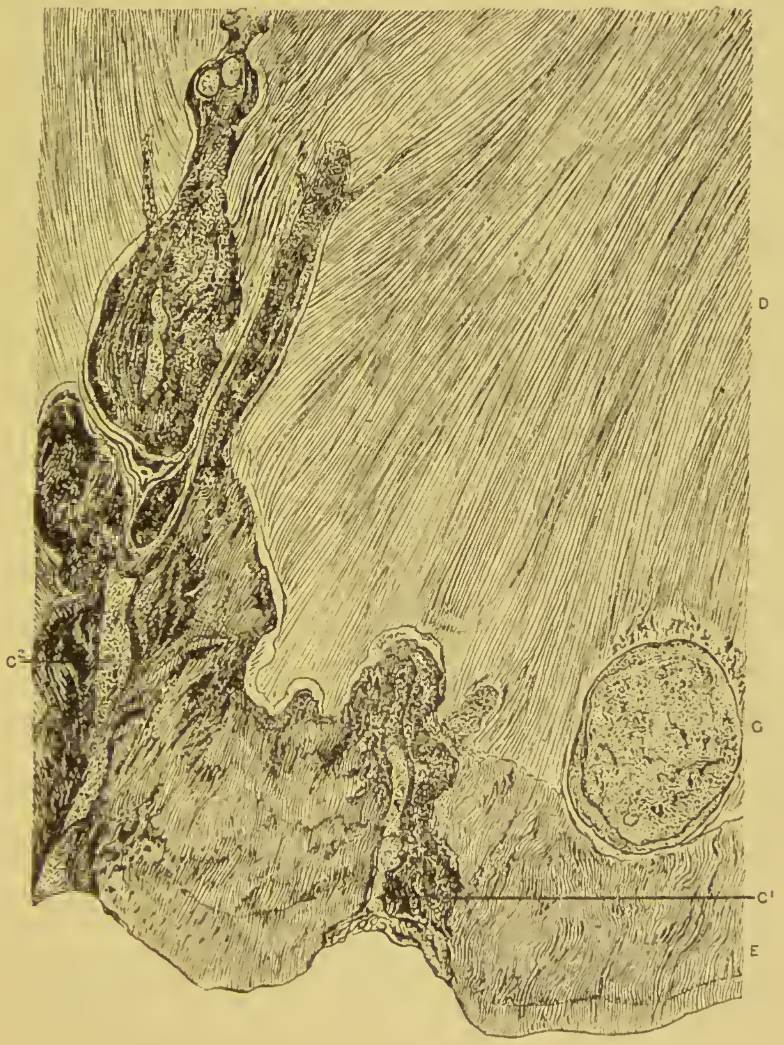
Right Upper Central Incisor of a Boy Twelve Years Old. Ground.

E, irregular pigmented enamel with vestiges of channels; *C*, pigmented channels penetrating the dentine; *B*, bare dentine; *G*, globule of ill-calcified dentine; *LP*, large bifurcated pulp-chamber; *SP*, small central pulp-chamber; *N*, nodule of pigmented enamel; *S*, *S*, secondary dentine at the borders of both pulp-chambers; *R*, narrow layer of cementum. Magnified 6 diameters.

had a weak constitution, and during the period of early childhood was often seriously ill. The boy did not have the upper central incisors till he was four years of age, and their permanent successors only made their appearance about the tenth year of age. It appears to be improbable that general or local disturbances should have influenced the malformation of this tooth. On the other hand, there is a strong corroboration of the theory of traumatic origin of the anomalous development of the tooth under consideration. At the cutting-edge we observe four channels, or rather vestiges of channels, where a series of foreign bodies were forcibly thrust into the enamel-organ shortly after birth, or at least during the first year of life. Judging from the arrangement of the slightly devious channels, I should infer that the foreign bodies were pliable, though rather firm and pointed. Such bodies are the bristles of a tooth-brush, which may have been either bitten into by the infant, or may by other accidental means have obtained entrance into the enamel-organ of the tooth. This view is the more plausible since we find a detached nodule of pigmented enamel at the floor of the central pulp-chamber, which evidently took origin from a torn-off piece of the enamel-organ. A portion of the dentine being destitute of enamel, this view gains the more ground, because the detached nodule of enamel corresponds in its devious direction to the other tracts of the channels. The tooth has a wide bifurcated pulp-chamber and a small central one, both exhibiting narrow layers of secondary dentine. The cementum is extremely narrow all over the root, and nowhere developed beyond the formation normally seen at the neck of the tooth. The root was somewhat compressed and grooved laterally. The arrangement of the channels and the injuries produced in the enamel are illustrated in Fig. 123.

The enamel is colored a light brown, and its prisms, besides being conspicuously wavy, exhibit irregularly-scattered pigmentations. In the vicinity of the channels the enamel is of a deep yellow-brown color; its prisms are but scantily developed, and in most places are replaced by a deep-brown amorphous mass. The dentine along the borders of the enamel-globules and pegs shows slight irregularities, consisting in a widening of the canaliculi, or in coarse conical offshoots filled with granules of lime-salts emanating from the enamel-pegs. Around the enamel-pegs the canaliculi converge. At the border between the enamel and dentine there is a globular formation, deeply stained with an ammoniacal solution of carmin. Higher powers of the microscope reveal that this globule is an anomalous formation of dentine. (See Fig. 124.) The basis-substance appears finely granular and arranged concentrically. It is traversed by extremely faint dentinal fibers running a radiating course. The periphery of the globule is surrounded by intensely-calcified globular masses, between which are seen interglobular spaces filled with protoplasm and granular deposits of

Fig. 123.

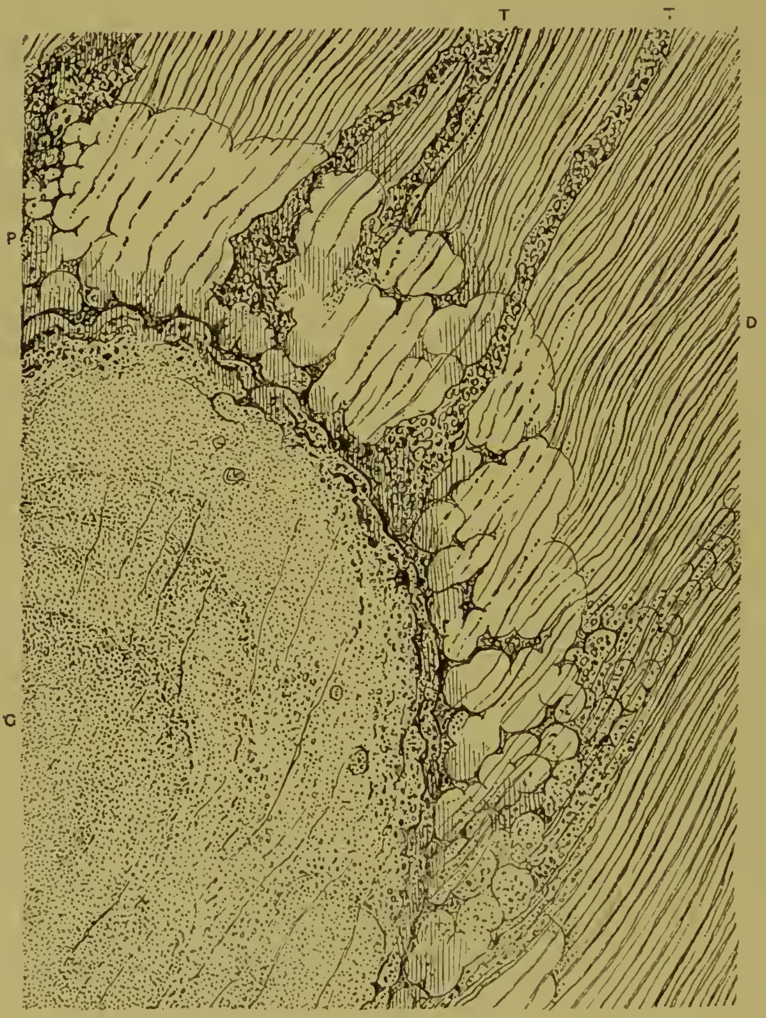


Portion of Enamel from Cutting-Edge of Crown of Fig. 122.

E, enamel, deeply pigmented; C^1, vestige of channel surrounded by a dark yellow-brown irregular enamel; C^2, vestige of channel bifurcating; *G*, globule of ill-calcified dentine; *D*, normal dentine. Magnified 25 diameters.

lime-salts. The globules are pierced by scanty and irregularly-formed dentinal canaliculi, which, however, keep the general direction of those of the normal dentine. Both the intensely-calcified zone around the globule, and the normal dentine, are traversed by broad routes of protoplasm pervaded with coarse granules of lime-salts.

Fig. 124.



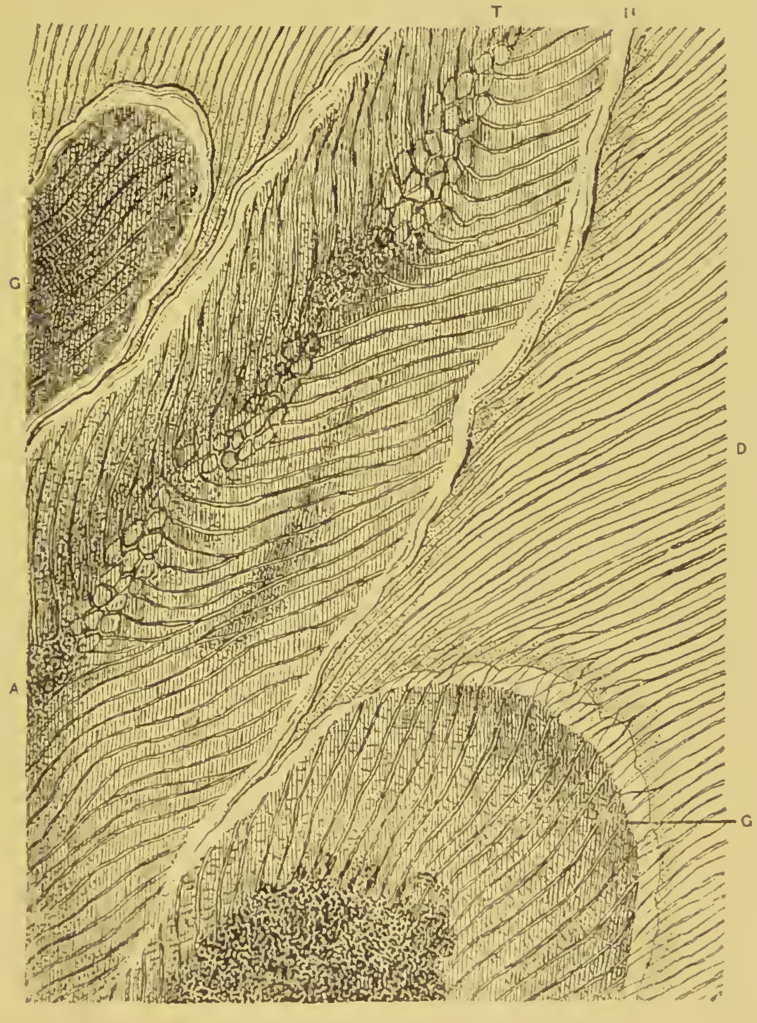
Globule of Ill-Calcified Dentine of Fig. 122.

G, basis-substance uncalcified, with scanty and faint dentinal canaliculi; *P*, globular calcareous deposits around the uncalcified basis-substance; *T*, *T*, tracts filled with calcareous granules; *D*, normal dentine. Magnified 500 diameters.

That the protrusions and pegs penetrating the dentine really are a formation of enamel-tissue, as is the nodule at the floor of the central pulp-cavity before alluded to, is proven by examination with higher powers of the microscope. (See Fig. 125.)

Furthermore, we notice enamel-prisms of an extremely devious course, the deviousness being most pronounced in the center of the peg, where a number of transverse sections of enamel-prisms are met with. Instead of such transverse sections, we frequently notice amorphous and deeply-pigmented granular masses, which probably are the result of crushed ameloblasts. The yellow-brown color of the anomalous formation of the enamel is everywhere due to the presence of such amorphous masses, whereas the enamel-prisms appear of a lighter dusky-

Fig. 125.



Portion of Interzonal Layer between Dentine and Enamel of Cutting-Edge of Fig. 122.

G, *G*, globular protrusions of pigmented enamel; *T*, tract of anomalous enamel; *A*, amorphous, deeply pigmented masses, replacing transverse sections of enamel-prisms; *H*, highly refractive rims between enamel and dentine; *D*, normal dentine. Magnified 500 diameters.

brown color. There is but little doubt that the pigment of the masses is due to a hemorrhage produced at the time of the injury. A noteworthy feature is the presence of an intensely-calcified rim between the globules and the pegs of the enamel and the dentine, which is traversed by the bifurcations of the dentinal canaliculi.

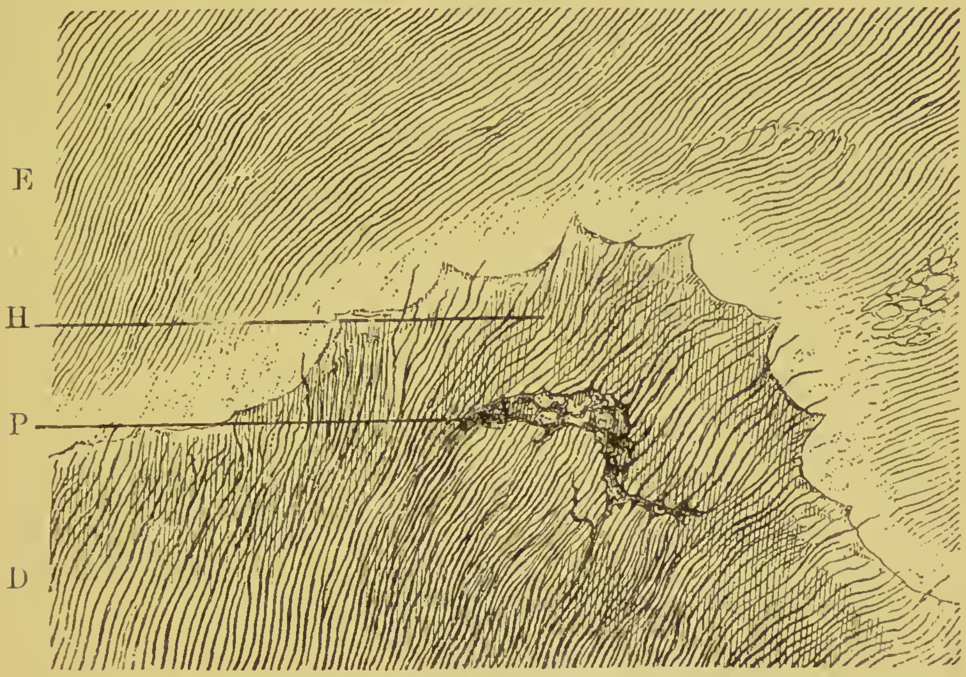
The writer has observed an interesting incident of faulty development in a family of four children and two grandchildren. The four children have no enamel upon their permanent teeth, while the teeth of both parents were covered with normal enamel. The teeth of all the children were abnormally small, and the incisors and cuspids even smaller than ordinary temporary teeth. Their external surface is smooth, of a dark-yellow color, and not abnormally sensitive to thermal changes. The molars mostly have the form of a lower first temporary molar, while the bicuspids are of normal form, but quite small. The cusps of all the molar teeth, when they made their appearance through the gums, were quite sharp, and, becoming a source of irritation to the tongue and cheeks, they had to be rounded off. These teeth soon decayed where the pointed cusps had been removed, and the inner portion of the dentine was extremely sensitive to the touch of the bur. The writer has lately seen the two grandchildren of this family, one of which is five and a half, the other six years of age. The latter child has normal temporary, and, as far as erupted, good permanent teeth, while the former has inherited the faulty-developed teeth of his father. This child, although only five and a half years of age, had its upper and lower permanent central incisors and the first permanent molars fully erupted. The remaining temporary teeth are the smallest teeth the writer has ever seen in any child's mouth. Their enamel, with the exception of the upper second temporary molars, appears to be normal. The latter four teeth each exhibit two pointed cusps, and seem to be devoid of enamel. The four permanent molars, which in general size and shape are nearer normal than those of his father's, are surmounted by four or five cusps respectively, and appear to be entirely devoid of enamel. The upper and lower permanent central incisors exhibit a bright-yellow color, and are also much larger than those of the father, while their surfaces seemingly lack enamel. They are marked by transverse grooves, principally upon their labial surfaces.

I shall make use of two valuable contributions to this topic by Frank Abbott.*

The first deals with anomalous occurrences in the enamel, as follows:

"**I. Anomalous Relation between Dentine and Enamel.**—In examining a large number of specimens of ground teeth, I met with formations in two instances which are to be considered as rather anomalous, though not strictly pathological. In one instance, that of a temporary molar, there was on the buccal surface a protrusion of dentine into the enamel with a fluted surface, or a surface fluctuating in a series of bay-like excavations. This fluting was present also at the junction of the dentine with the enamel in general, but not so marked as in this protruding spot. The center of this protrusion was occupied by an eccentric protoplasmic formation, differing in shape from the ordinary interglobular spaces. The dentinal fibers at the periphery were bifurcated in the usual manner, but very

FIG. 126.



PROTRUSION OF DENTINE INTO ENAMEL.

E, enamel; *D*, dentine; *H*, hill of dentine with fluted summit; *P*, protoplasmic bodies in the dentine. Magnified 400 diameters.

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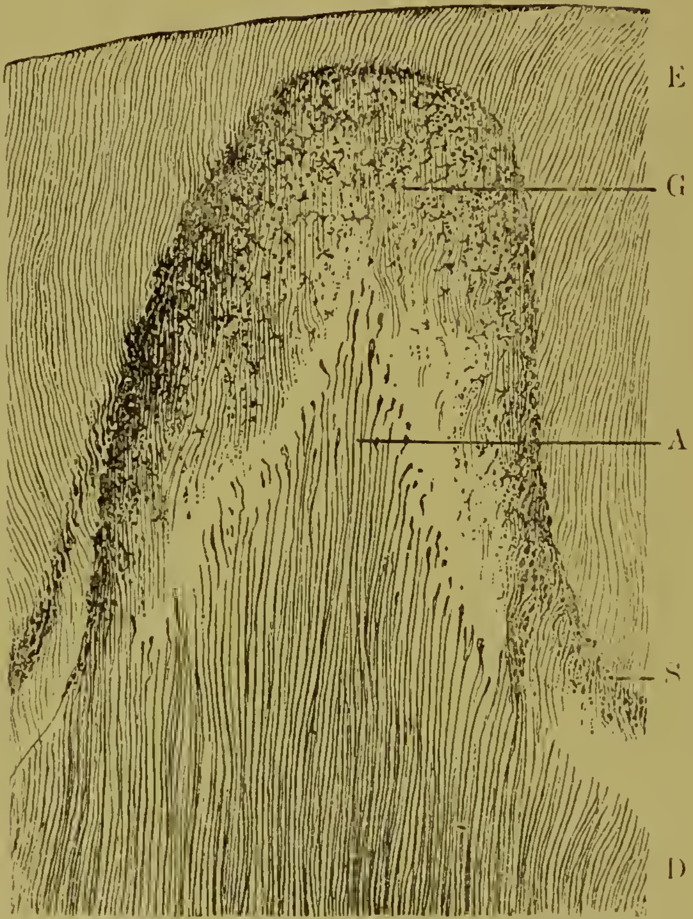
* "Studies of the Pathology of Enamel of Human Teeth, with Special Reference to the Etiology of Caries." *Dental Cosmos*, 1885.

few of them penetrated the enamel. The portion of the enamel nearest to the protrusion was destitute of prisms, while in the immediate vicinity, again, of this portion such prisms were traceable almost in contact with the dentine. The zone immediately above the protrusion was but slightly brownish, whereas the prisms of the enamel exhibited a very distinct brown pigmentation.

FIG. 127.



PROTRUSION OF DENTINE INTO PATHOLOGICAL ENAMEL.

E, enamel; *D*, dentine; *G*, granular enamel; *A*, summit of the dentine; *S*, sloping borders of the granular enamel. Magnified 200 diameters.

"In a second case, that of a permanent cuspid, a protrusion of dentine was observed, as in the former instance, on the buccal surface near the edge, occupying nearly one-half of the breadth of the enamel. This protrusion was of a conical shape, and without a distinct boundary, but blended with an oblong field of enamel of quite remarkable structure. The dentinal canaliculi exhibited at their peripheral portions numerous bifurcations, and terminated in small pear-shaped enlargements, many of which could be traced in connection with dentinal fibers, whereas the most peripheral ones, owing to their devious course, looked isolated. The adjacent enamel showed but very indistinct rods, the main mass of the enamel being occupied by brownish globular fields, separated from one another by irregular interstices closely resembling the interglobular spaces of dentine, though of considerably smaller size. The deepest pigmentation and the largest number of such *interprismatic* spaces occurred along the periphery of this anomalous formation, especially toward the outer surface of the enamel. The vicinity of the enamel proper was marked by the presence of slightly pigmented rods, more wavy in their course than is normal. Toward the dentine the anomalous formation was sloping, and the line of demarcation between the normal and anomalous enamel exhibited either brown and very wavy prisms or small *interprismatic* spaces, decreasing in diameter the nearer they approached to the dentine. I wish to emphasize and call particular attention to the fact that the dentine of this tooth was nowhere traversed by interglobular spaces, the anomalous construction being confined to the enamel.

"**II. Stratification of Enamel.**—It is known that dentine, without exhibiting pathological features, yet slightly deviating from its normal structure, is sometimes composed of strata that are more or less distinctly marked, and are altogether independent of the formations known as secondary dentine. We often meet with similar formations in the enamel. We observe, varying in width and more or less sharply marked by a straight line, layers which in longitudinal sections of teeth are concentric, the broadest part corresponding to the cusps, the narrowest to the neck of the tooth.

"At the outer periphery of the enamel there may occur strata, which, contrary to the general construction as above described, are broadest toward the neck and narrowest toward the cusp, though never reaching its summit. In transverse sections the enamel shows simply concentric lines, separating from one another layers of greatly varying diameters. With higher powers of the microscope we ascertain the fact that the lines of stratification, as a rule, do not alter the general course of the enamel-prisms,—in other words, a single enamel-prism will show an oblique line of demarcation, corresponding to the

FIG. 128.

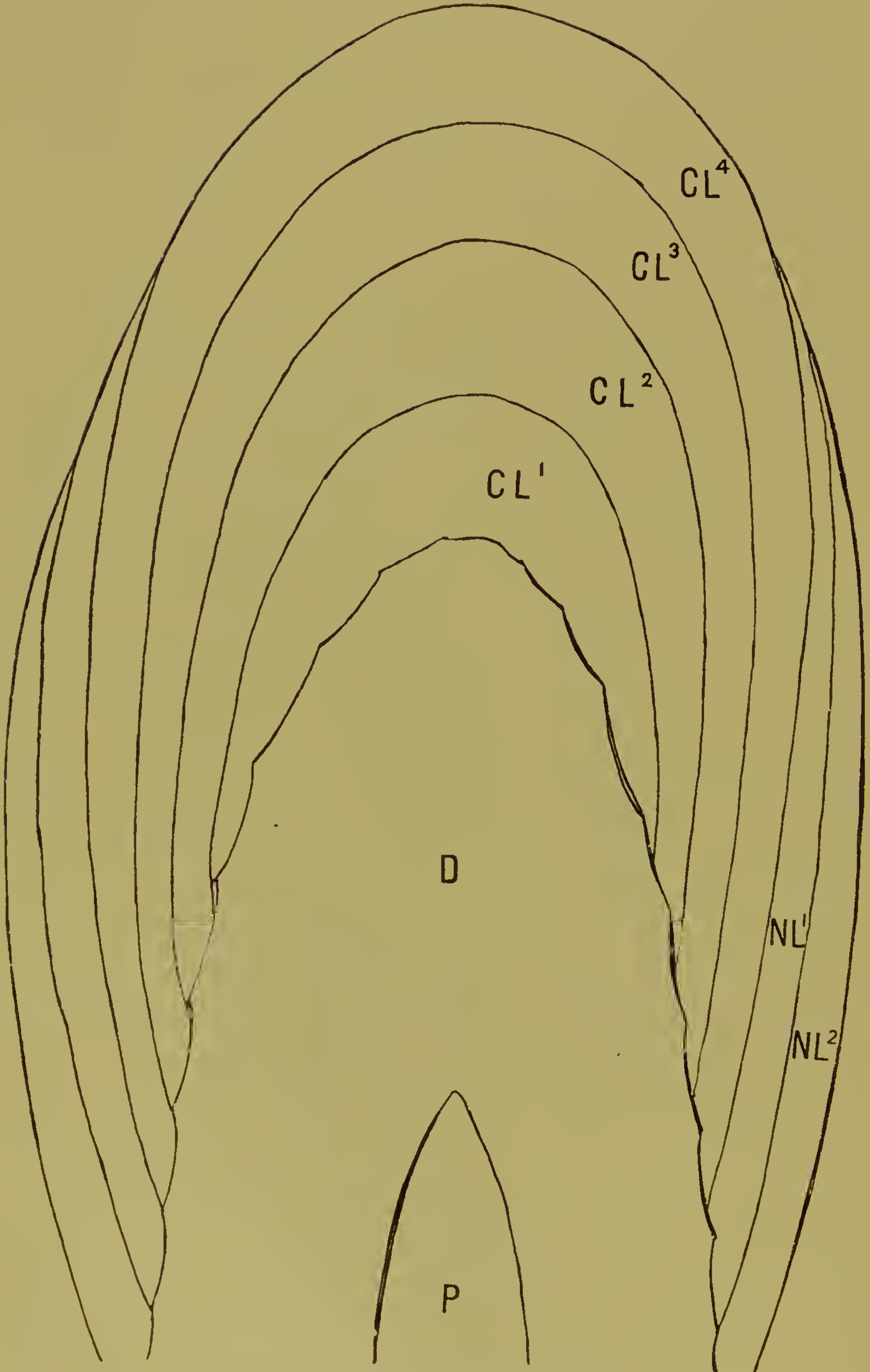


DIAGRAM OF STRATIFICATION OF ENAMEL.

P, pulp-chamber; D, dentine; CL^1, CL^2, CL^3, CL^4, cusp-layers of enamel; NL^1, NL^2, neck-layers of enamel.

general line of stratification, without being altered in its construction or its course. An exception to this rule will occur only at the peripheral portions of enamel, occupied by the tapering ends of the above-described secondary strata, which I would like to term *neck-layers*, in contradistinction to the central *cusp-layers*. The tapering ends of the neck-layers may exhibit enamel-rods, almost parallel with the surface of the enamel, a feature which is never seen at the outer periphery of the cusp-layers, where the enamel-rods are invariably directed more or less perpendicularly to the surface.

"An understanding of the stratification of the enamel is of the utmost importance in aiding the understanding of its pigmentation and granulation. As I will show later on, both the pigmentation and granulation correspond to the general strata of the enamel, thus showing in longitudinal sections of teeth a fan-like appearance.

"It can scarcely be doubted that the stratification of this tissue is in close relation to the history of its development. We know that the first appearing enamel-cap of temporary teeth, in the seventh month of intra-uterine life, has the configuration of the innermost cusp-layer,—*i.e.*, it is broadest in the direction of the future cusp, and tapers toward the future neck of the tooth. It seems reasonable to assume that the subsequent layers of enamel form on the plan of the first, but there may be a temporary stoppage of its construction, due, perhaps, to slight ailments of the mother before delivery of the child, or slight ailments of the infant after delivery, which causes interruptions in its organization. Slight ailments of a general nature will not interfere with the final result of an otherwise sound enamel; whereas severe ailments, particularly local ones, may lead not only to stratification, but to a decidedly pathological condition, which I have before called pigmentation and granulation. These conditions invariably involve a deficient deposition of lime-salts.

"**III. Anomalous Arrangement of the Enamel-Rods.**—In normal enamel, longitudinal sections will, in the majority of cases, exhibit slightly wavy rods, interlaced by comparatively small bundles, cut in a transverse direction. Toward the periphery the curvatures of the rods gradually become less, until, when close to the surface, they present a nearly straight course. I have never seen transverse sections of enamel-rods directly in contact with the interzonal layer.

"Deviations from this rule seem to be rare. Where they exist, the enamel-rods seem to lack all regularity in their arrangement. It may occur that close to the interzonal layer the enamel-rods show extensive fields occupied by these transverse sections, which gradually blend with oblique and longitudinal ones, producing a wavy appearance, to such an extent that beautiful figures arise, reminding one of the grain of *lignum-vitæ*. Still more complicated figures arise if the transverse bars of the longitudinal rods are unusually conspicuous. In such enamel it may occur that the curvatures of the rods remain very marked up to the surface; and, consequently, groups of transverse sections may be seen directly at the outer surface.

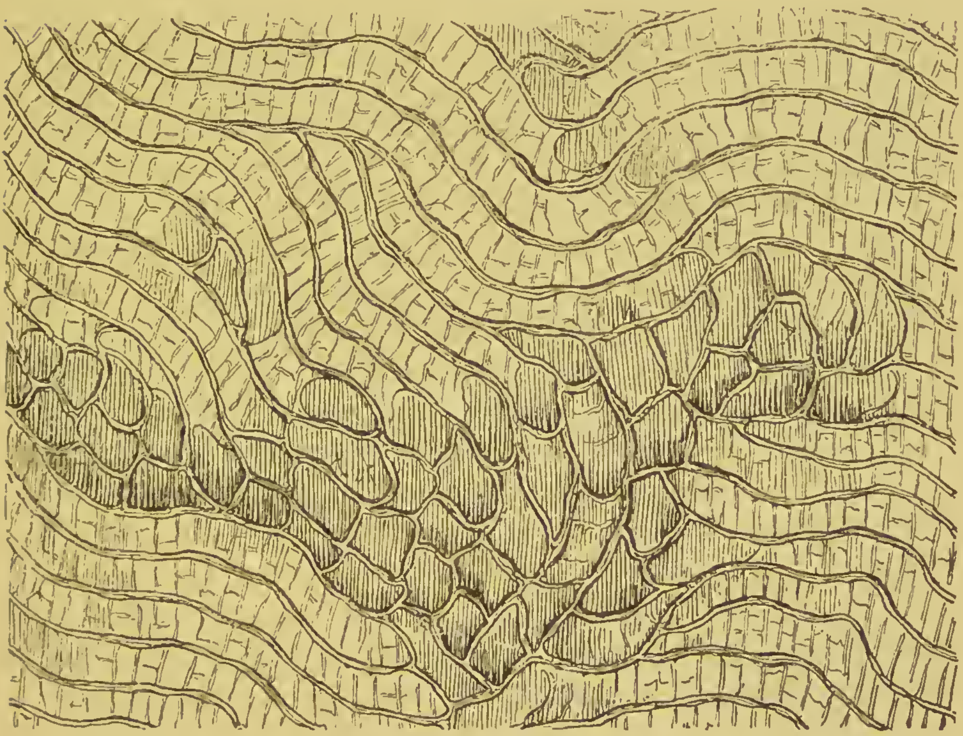
"Enamel of this description may be seen only on one portion of the tooth, while the rest is normal. In all my specimens, pigmentation is combined with this curly appearance of the enamel-rods as a marked feature, and the interstices between the rods are a trifle wider than normal. Both of the latter features must imply a deficient calcification, and, consequently, extreme brittleness. It is very difficult to obtain perfect specimens of such enamel. The dentine subjacent to such anomalous formations is freely supplied with interglobular spaces, which fact is likewise a sign of deficient calcification.

"**IV. Deficient Calcification of the Enamel, without Pigmentation.**—The friability alluded to under the previous heading is in some instances very marked,—so much so that it is impossible to obtain an unbroken slab of a tooth, even with the finest grinding-stones. With low powers of the microscope we observe that the broken ends of the enamel-rods look as if corroded, or as if some of them had been displaced or torn off by the process of grinding. Neither pigmentation nor an anomalous course of the enamel-rods is necessarily connected with such a condition of the tooth. The most striking feature, however,—a feature visible even with low powers,—is that the enamel-rods are unusually narrow, the interstices between them unusually wide, and their tenants, the enamel-fibers, very prominent. The cross-lines of the enamel-rods are likewise considerably widened and irregular, so that the fields of basis-substance look unusually small and irregular. The reticulum in the immediate vicinity of the interzonal layer is also unusually prominent.

"Such a condition of the enamel may occur both in temporary and permanent teeth, and may be combined with pigmentation. It is a feature of such deficient enamel that it readily stains with an ammoniacal solution of carmin, something that normal enamel will not easily do. The subjacent dentine, under such conditions, may either be perfectly developed, as before stated, or be deficient in its formation, as shown by the presence of more or less numerous interglobular spaces.

"All clinicians have observed, in the enamel of teeth, congenital white or yellow spots, which, if broken into, are found to be of the consistence of chalk. Such spots have been termed 'white decay,' although they do not correspond to the process of caries as we usually understand it. They mean nothing but deficient calcification. Again, all clinicians have seen teeth across which runs a row of pit-holes, in the bottom of which depressions, in many instances, no enamel is to be found. This condition, also, is always congenital, and closely related in its

Fig. 129.



Extremely Irregular Course of Rods in Slightly-Pigmented Enamel.

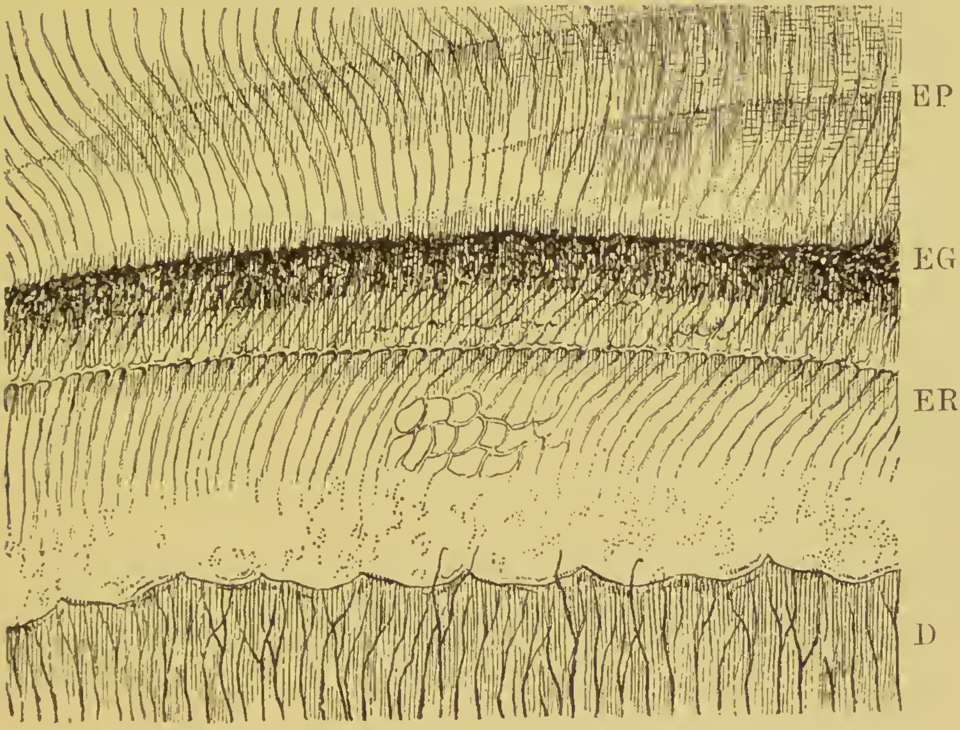
The longitudinal rods deviating to a great extent from the field of the specimen, show oblique and transverse sections. The interstices are widened and contain conspicuous enamel-fibers. Magnified 1200 diameters.

origin to pigmentation and the white or yellow spots. In other instances an originally smooth enamel is mutilated mechanically by the process of mastication, with the result of loss of substance, with abruptly broken, jagged edges. Again, we see teeth with a great portion of their crowns covered by a brownish-yellow substance in place of enamel, this substance being so soft as to be easily removed, leaving the dentine bare of its covering and extremely sensitive to the touch of an instrument, the pressure of food in mastication, etc. These conditions, again, are, in most instances at least, connected with the presence of pigmentation and the white or yellow spots. We might call them exaggerated cases of the same condition. Obviously these congenital defects are dependent upon deficient deposition of lime-salts in the basis-substance, rendering the enamel less resistant and more friable.

"**V. Pigmentation of Enamel.**—One of the most common anomalous conditions of the enamel is its pigmentation. Sometimes it is so slightly marked that the naked eye discovers only a slight yellow-brown discoloration; in other instances it is quite prominent and readily discernible. Correspondingly, specimens of such teeth under the microscope will exhibit either a dim yellow tint in the enamel or a marked brown discoloration. The pigmentation may occur either in non-stratified or in stratified enamel. In the first instance there is no demarcation of the brown spot toward the colorless enamel: only faintly-marked offshoots of the main spot, tapering toward the dentine, and running in an oblique direction, will indicate the fact that pigmentation has occurred during its formation. In the second instance, on the contrary, if pigmentation invades stratified enamel, there is a close relationship between the two, inasmuch as the deepest stain invariably corresponds to the boundary line of the strata, tapering toward the neck, and gradually fading toward the proximal end of each stratum. Thus, in longitudinal sections, a beautiful fan-like configuration is produced.

"The pigmentation may invade all layers of the enamel, often being more marked in the deeper than in the superficial portions. Higher powers of the microscope reveal the following facts: First, that the brown discoloration concerns the basis-substance of the enamel-rods only. Secondly, that the interstices between the pigmented enamel-rods are widened,—not merely to seeming, and in consequence of the contrast in color, but because of a deficiency in the formation of the basis-substance. Thirdly, that the transverse lines of the enamel-prisms likewise are (at least in many instances) enlarged. Fourthly, that the enamel-fibers and their lateral offshoots are more conspicuous than in normal enamel, and more so even than in the enamel of temporary teeth, and in many places distinctly beaded. Pigmented portions of the enamel are rather prone to take up a red stain on being treated with an ammoniacal carmin solution.

FIG. 130.



PIGMENTED AND GRANULAR ENAMEL.

D, dentine; *ER*, layer of slightly pigmented rods broken off; *EG*, layer of highly pigmented and granular enamel; *EP*, stratified pigmented enamel. Magnified 400 diameters.

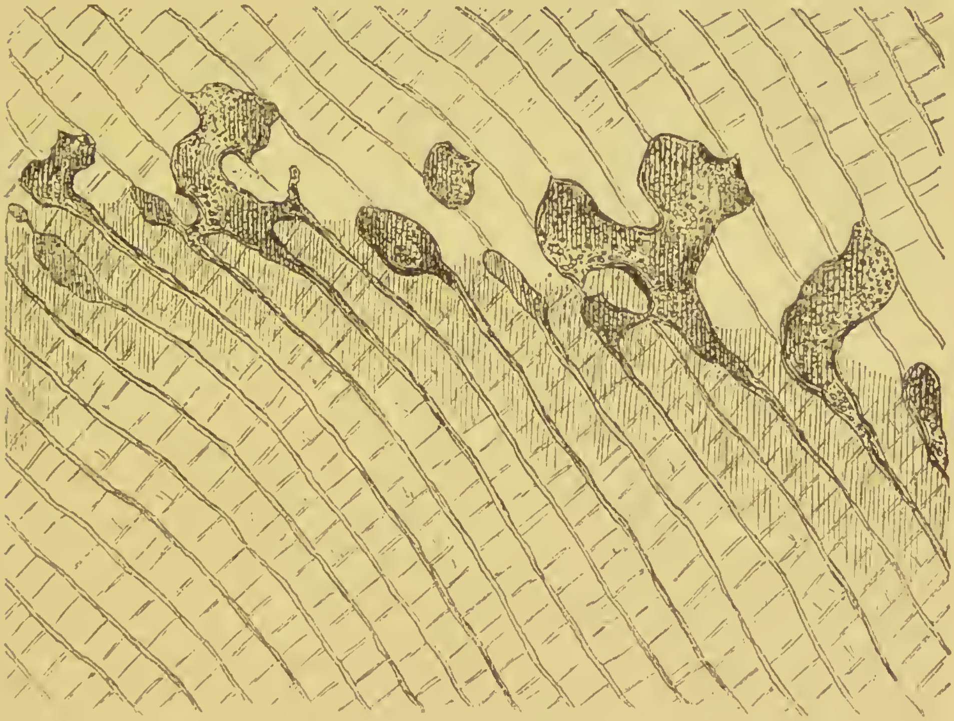
"As to the origin of the brown discoloration, I have to say, as a suggestion simply, that at the time of the formation of this tissue there must have been a disturbance in the enamel-organ which interfered with the proper construction of the basis-substance and the deposition of lime-salts. What this disturbance really was, I am unable to say. Many pigments of the body depend upon and are closely related to the coloring-matter of the blood. I am loth, however, at this time, to attribute pigmentation of enamel to the extravasation of blood-corpuscles or diffusion of the coloring-matter of the blood. Careful studies in the history of the development of this tissue must be made, before an attempt at a solution of this question will be admissible. One point I am positive about, however, is that this pigmentation is congenital, invading temporary as well as permanent teeth. Acquired pigmentation of enamel seems to be of comparatively rare occurrence, except as a result of caries. I have seen pigmentations of its surface, of a deep orange color, not penetrating the enamel-tissue in the least. Caries on the surface often causes an orange discoloration, diffused and fading toward the normal portions. Several of my specimens plainly show an invasion of the enamel by caries, on spots pigmented congenitally; secondarily, an orange diffused discoloration has taken place, and here the enamel is likewise prone to take up the carmin stain; thus beautiful shadings of brown, orange, and red are to be seen, the brown being congenital substances, the orange acquired, and the red artificial. What chemical may lead to an acquired pigmentation or discoloration of the enamel I cannot say.

"**VI. Granulation of Enamel.**—Under this heading I propose to describe a peculiar abnormality, which, so far as my specimens indicate, is by no means rare. It consists of pear-, spindle-, and club-shaped spaces in the middle of the substance of the enamel. Such spaces were known to exist heretofore at the junction of the dentine and enamel only. They may appear in pigmented, and invariably do in stratified, enamel; the stratification in the latter instances being due to their presence. Club-shaped spaces may appear at the distal boundary of one of the cusp-layers, or there may be several rows of such spaces, varying in extent and degree, but it sometimes occurs that only the outermost cusp- or neck- layers are freely supplied with them, whereas the rest of the enamel is normal or more or less pigmented.

"Higher powers of the microscope demonstrate that the spaces are enlargements of the interstices between the prisms and the tenants of the interstices. The enamel-fibers are in direct connection with the contents of the spaces,—*i.e.*, with living matter. The spaces, at their stem-like beginnings, run, accordingly, parallel with the interstices; but in their broader portions may cross the enamel-prisms in different directions.

If they are few in number they may protrude from the boundary line of a cusp-layer, and penetrate the adjacent cusp-layer obliquely to the main direction of the enamel-rods. In this instance I could trace the connections of the enamel-fibers even with the club-shaped ends projecting into the neighboring cusp-layer. If these spaces are present in large numbers, the enamel, with lower powers of the microscope, will look dark and granular; hence the name, 'granulation of enamel,' which I have given it.

Fig. 131.



Granular and Slightly Pigmented Enamel.

Club-, spindle-, pear-shaped, and irregular spaces at the boundary of a cusp-layer in the middle of enamel. Magnified 1200 diameters.

"Fig. 127 represents this condition of granulated enamel, with a low power.

"Fig. 131 shows the condition under a high power.

"In stratified and granular enamel, single strata may be produced by an interruption of the pigmented enamel-rods, by convex ends directed toward the adjacent peripheral cusp-layer. (See Fig. 130.)

"The *interprismatic* spaces of the enamel bear some resemblance to the interglobular spaces of the dentine. I have seen both conditions in a highly-marked degree present in one of my specimens. Whenever these *interprismatic* spaces are present along the border of a cusp-layer, they considerably lessen the degree of consistence of the enamel, which, upon being ground, easily breaks off along the dark granular line.

"The nature of the *interprismatic* spaces is plain enough. They mean an incomplete formation of the enamel, owing to some deficiency of function in the enamel-organ during its formation. Obviously, not only the basis-substance is deficient, but also the amount of lime-salts is considerably less than normal; hence its brittleness and proneness to decay.

"Under the foregoing headings I have described a number of anomalous conditions of the enamel, which, at least so far as stratification, pigmentation, and granulation are concerned, mean a deficient formation of the basis-substance, together with decreased deposition of lime-salts. These conditions are, in my judgment, of the utmost importance in the etiology of caries. Ailments either of the mother during gestation or of the infant in the earliest periods of life, obviously cause such anomalies in this tissue. These ailments are known to occur far more frequently in refined people, debilitated, as it were, by civilization, than in strong, hard-working, plain-living people, continually engaged in a struggle for life. Thus, I have directly demonstrated and anatomically shown, in a measure, at least, the reasons why refined people are far more subject to caries of the teeth than people lacking such refinement."

The other contribution, by Frank Abbott, to the knowledge of faulty development of enamel is *Congenital Defects in Enamel*.*

"Every dental practitioner is more or less familiar with the condition of imperfect or defective enamel upon the crowns of permanent teeth (more especially the incisors and first molars), which I propose to consider under the above heading. These imperfections usually concern the summit of the crown or its vicinity. We see upon an otherwise well-developed crown an almost circular ridge, above which the enamel appears of a grayish-brown color, and in the shape of numerous pointed, thorny projections, the masticating surface of molars appearing as if provided with numerous minute stalactites or stalagmites. (See Fig. 132.)

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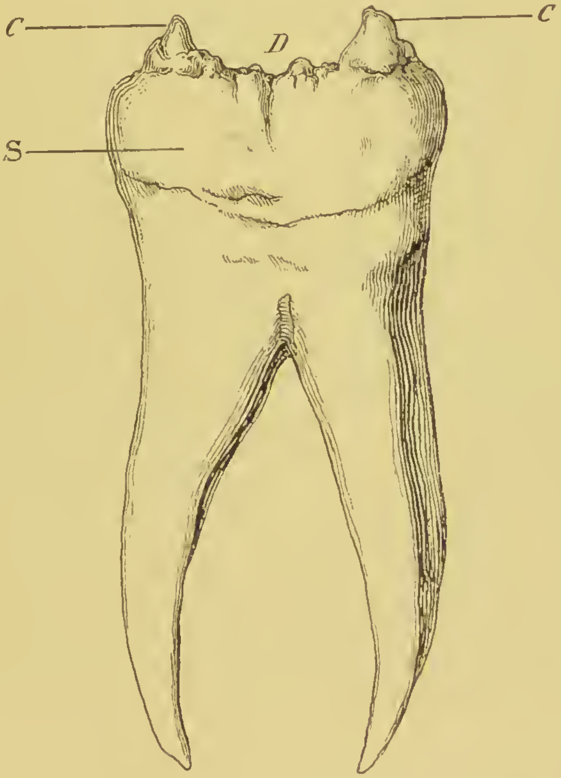
* *Dental Cosmos*, 1891.

" In some cases there are only a few blunt or pointed protrusions of enamel, between which the dentine is entirely destitute of such covering. In others the dentine is nearly covered with enamel, leaving rows of small round or oblong holes through it to the dentine. These features appear, as before stated, only in permanent teeth, and very seldom are any except the incisors and first molars involved. Whether or not the complete absence of enamel from the crowns of incisors, as is sometimes seen, is of the same nature, and due to the same causes, I am not prepared to say, although it seems probable.

FIG. 132.



CONGENITALLY IMPERFECT CROWN OF LOWER MOLAR.

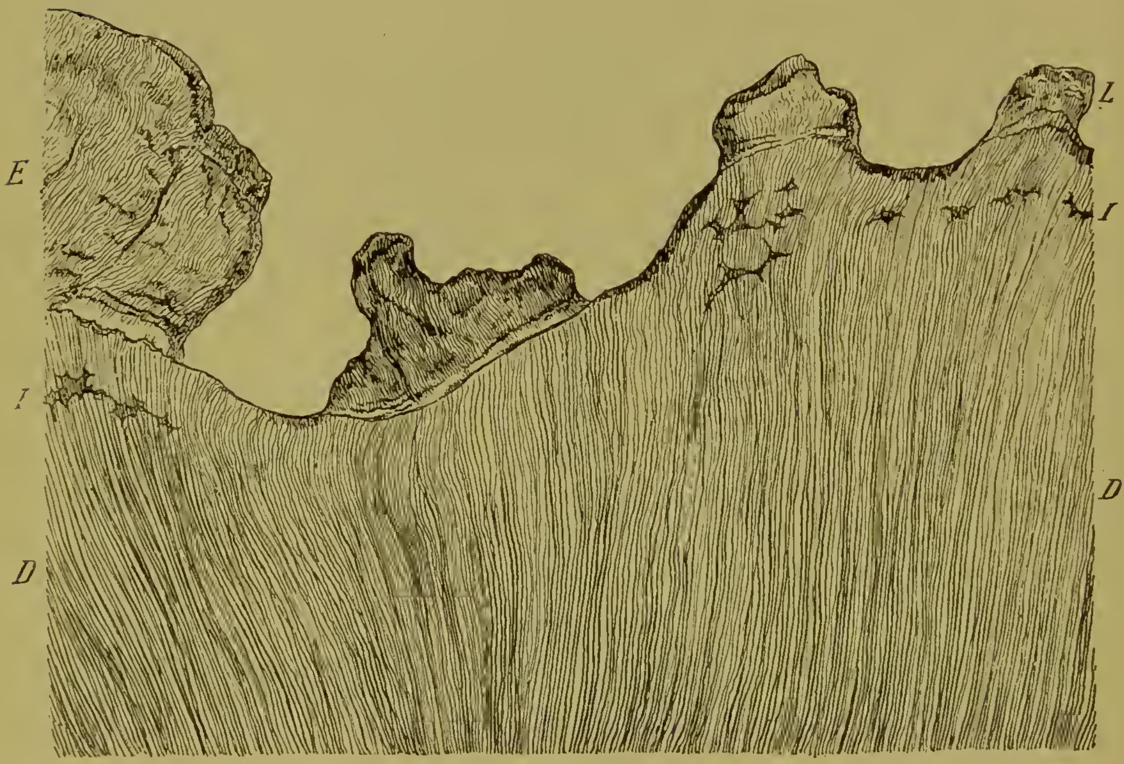
S, shortened crown; *C*, *C*, cones of enamel; *D*, dentine without enamel covering. Magnified 4 diameters.

" In looking with the naked eye at a longitudinal section through a molar, affected as just described, we at once recognize the deficiencies of enamel, the stalactite or stalagmite appearance, and the shortening of the crown by about one-eighth of an inch, caused by these deficiencies.

" These blunt and pointed elevations are made up partly of healthy-looking and partly of a yellowish-brown enamel. Between the elevations are areas partly covered by an extremely thin layer of enamel and partly destitute of it. By grinding the crown of such a tooth in longitudinal section for microscopical examination, the masticating surface presents an extremely striking image. (See Fig. 133.)

"A well-developed, though slightly-pigmented, enamel is seen to be gradually tapering toward the masticating surface, showing marked deficiencies of the outermost layer. These deficiencies consist of conical depressions at the surface and granulations near it. Obviously this condition was caused by an incomplete calcification of the enamel, from the fact that it has taken up or absorbed a deep brown pigmentation. The tapering layer of enamel stops abruptly, leaving the dentine entirely uncovered, as is seen in several places; besides, there are irregular hilly protrusions of an enamel of a deep brown color. These are the protrusions furnishing to the grinding-surface the appear-

Fig. 133.

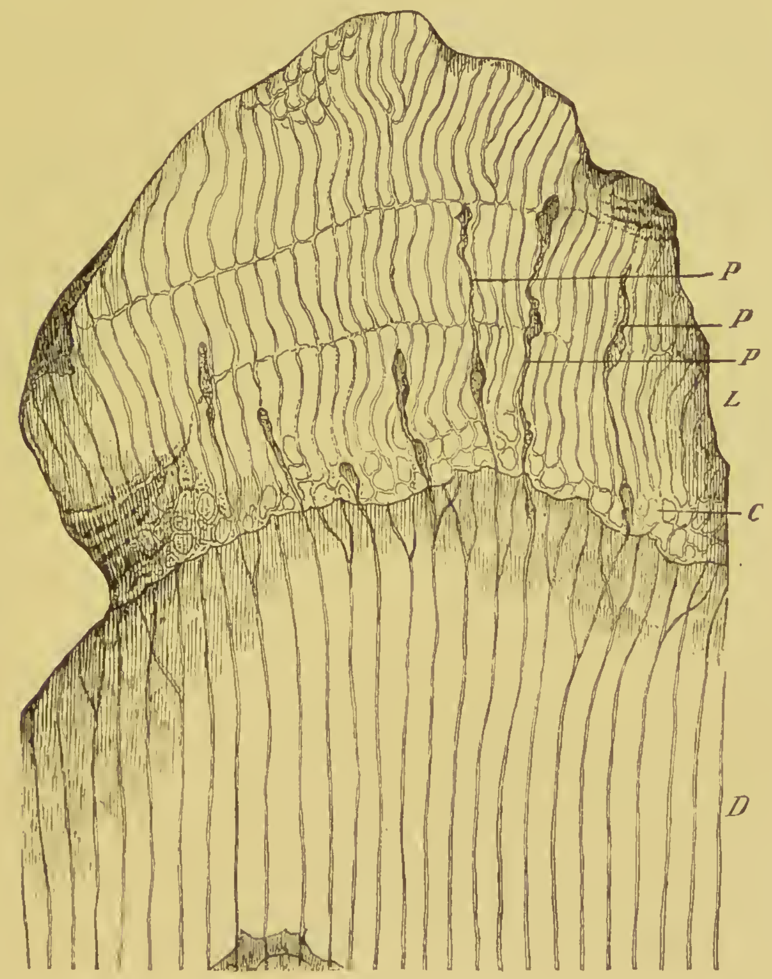


Section of Masticating Surface, showing Partial Covering of Enamel.

E, well-developed enamel: *L*, isolated lumps of enamel; *D*, *D*, dentine; *I*, *I*, interglobular spaces. Magnified 100 diameters.

ance of groups of stalactites. Slabs exposed to the action of a half per cent. solution of chloride of gold for one hour, exhibit a dark violet color of the dentine in the crevices between the enamel-lumps, which means that a portion of the lime-salts has been dissolved out, although no destruction of the organic portion of the dentine has taken place. At the usual distance from the interzonal layer are seen interglobular spaces.

FIG. 134.



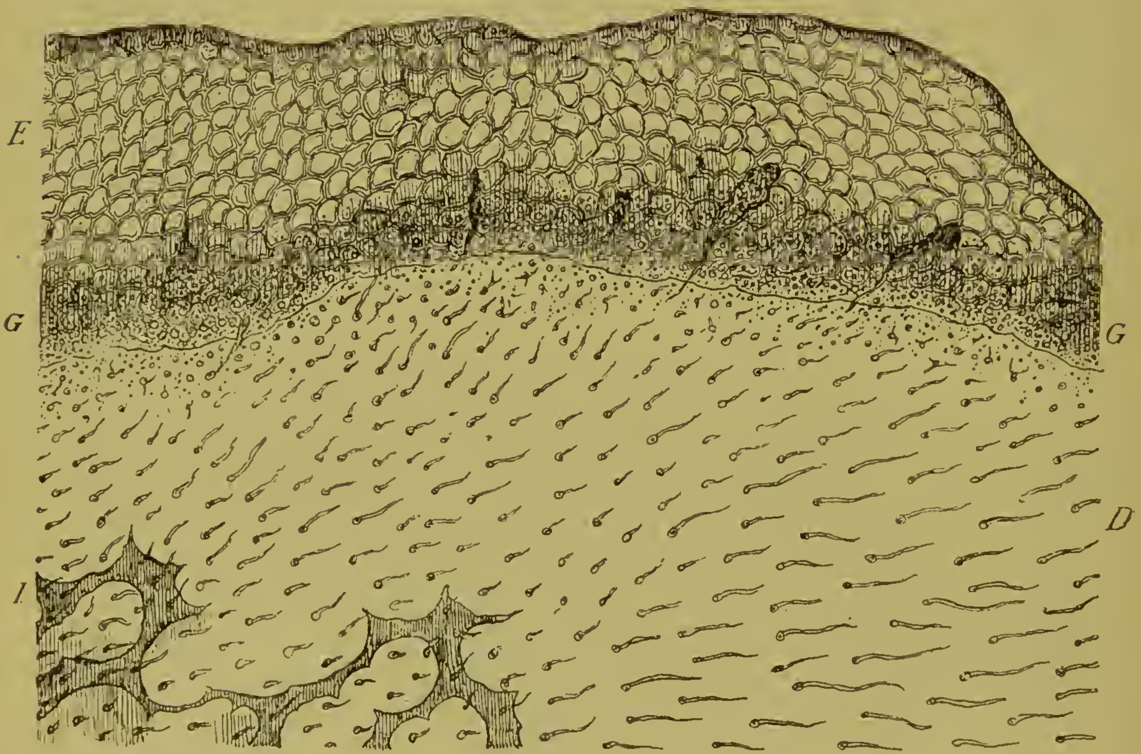
ISOLATED LUMP OF ENAMEL, VERY IMPERFECT.

P, P, P, protoplasmic projections into the enamel from the dentine; *C*, transverse section of enamel-prisms; *D*, dentine. Magnified 500 diameters.

"Let us magnify a lump of enamel in this locality five hundred diameters. (See Fig. 134.)

"We notice in this specimen narrow prisms, markedly wavy, and interrupted by faint concentric striations. The prisms, as usual, do not reach the surface of the dentine, but at a given distance from it they are replaced by irregular angular pieces. The outermost portion of the lump is of a dark brown color. Penetrating the enamel at varying heights are seen numerous pear-shaped prolongations of the dentinal canaliculi, some extending nearly to the surface. These spaces contain protoplasm, and have become stained a deep violet color by the chloride of gold. Aside from these irregularities the lump seems to be thoroughly calcified, except in a few spots upon the surface, which have taken a slight violet stain. The exposed dentine is also deeply stained the characteristic violet color in this locality, denoting insufficiency of lime-salts, or an excess, over the ordinary, of organic material.

FIG. 135.



IMPERFECT ENAMEL.

E, well-developed enamel, transverse section; *G*, *G*, granular layer of enamel, with pear-shaped protoplasmic enlargements; *D*, dentine, canaliculi in transverse and oblique sections; *I*, interglobular spaces. Magnified 800 diameters.

"In some instances the crown of the tooth may be nearly covered with a well-developed or a stratified and slightly-pigmented enamel, the other portions being coated with a thin layer highly pigmented, again denoting deficiency in lime-salts. (See Fig. 135.)

"We present here a transverse section of the crown of a molar. The thin and irregularly-contoured enamel exhibits only transverse sections of prisms, of a deep brown color. At the interzonal layer numerous pear-shaped protoplasmic spaces are seen penetrating the enamel, and in the region nearest the dentine the prisms appear as if granular or sieve-like (perforated with numerous small holes), indicative of a lack of proper calcification.

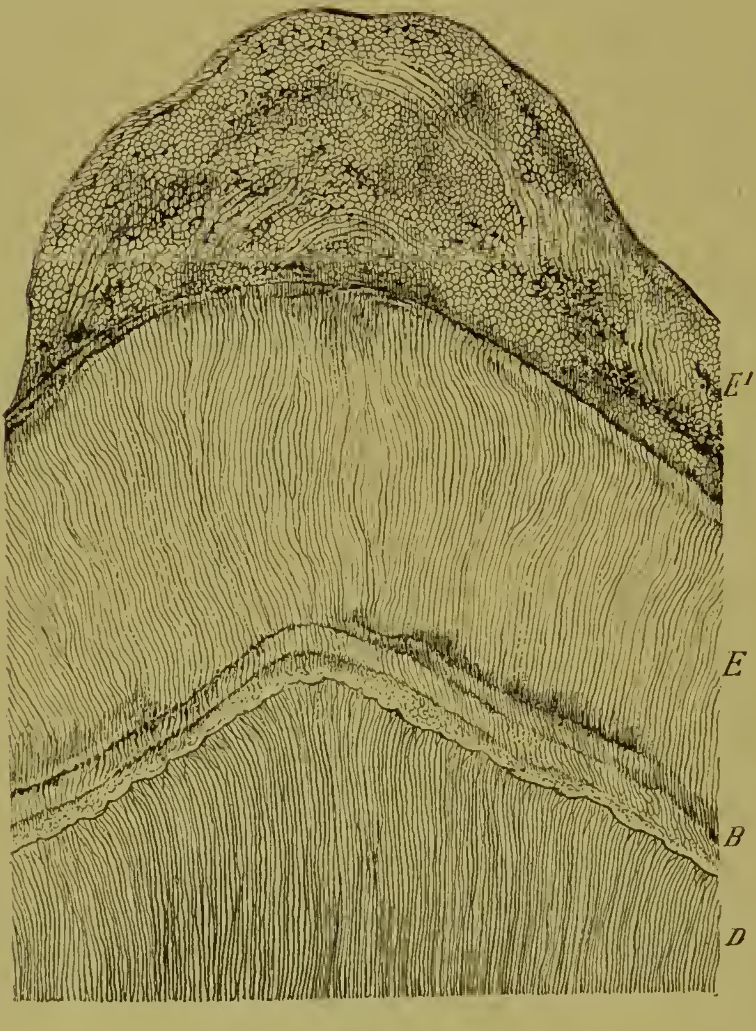
"I will now call attention to some extremely interesting and instructive anomalies in the formation of this tissue,—viz, two distinct varieties of enamel, one upon the other. First we have the anomalous portion grafted or deposited upon a normal enamel, and again anomalous enamel first deposited, with the peripheral portion fairly normal. (See Fig. 136.)

"This represents a cusp of a molar, with a conspicuously deficient enamel, deposited upon a nearly normal one. The normal portion is slightly pigmented, slightly stratified, and supplied with a moderate number of granulations, near the interzonal layer. The outer or peripheral portion exhibits a layer which ends abruptly on one side, and gradually blends with the normal enamel on the other. This portion is remarkably deficient in its structure. At the boundary-line between the two portions the enamel-prisms become abruptly devious, their longitudinal course being suddenly changed to a transverse one. In the latter portion a few oblique sections are seen alternating with the transverse. The whole portion superadded to the normal is pierced by innumerable granulations, which, owing to their violet color, we must conclude as protoplasmic in structure, and, of course, deficient in lime-salts. The granulations are, in some places, arranged in rows, in others scattered irregularly. If a large mass of enamel exhibits prisms almost rectangular to their original normal direction, it is not an evidence of interlacing of such prisms, but of their unusually wavy courses. An originally deficient enamel, upon which is deposited a normal one, is represented in Fig. 137.

"Here we observe numerous layers made up of extremely narrow, interrupted prisms, and at a given line prisms of normal width appear, first in transverse, then in longitudinal sections. This specimen affords a good opportunity to trace one and the same prism in longitudinal, oblique, and transverse section.

"In all the teeth with imperfect enamel that I have examined, the so-called interglobular spaces were present in the dentine, indicating a deficient calcification of territories at the period of development which corresponds with that of the formation of enamel. In only one specimen have I seen a devious course of the dentinal fibers and stratification of the dentine.

FIG. 136.



IMPERFECT, GRAFTED UPON PERFECT ENAMEL.

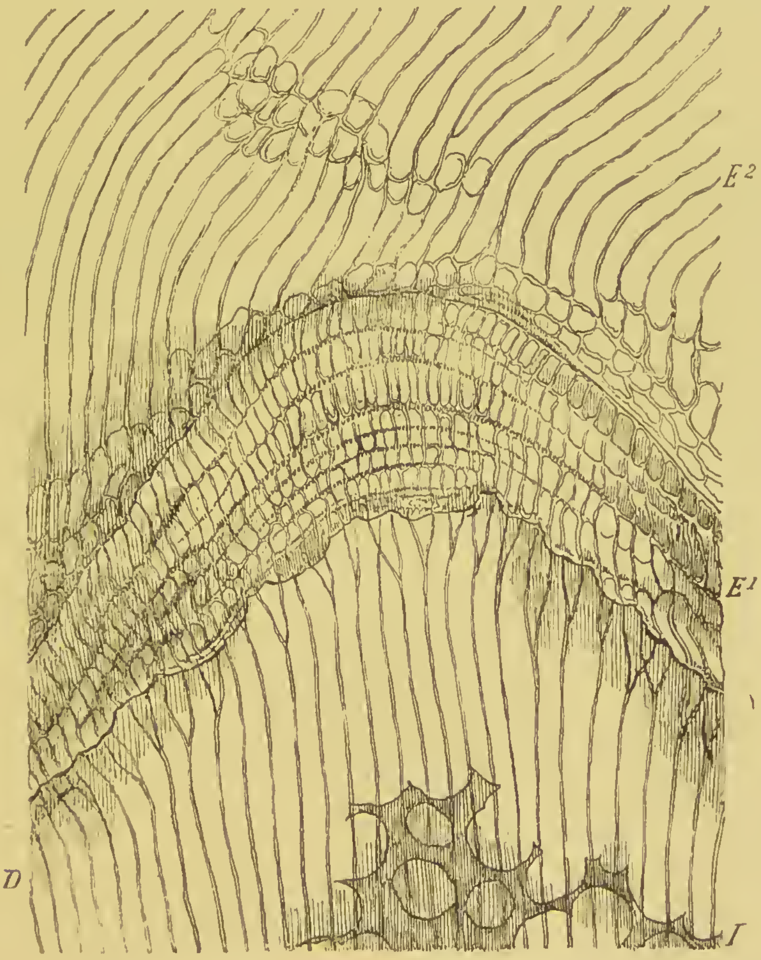
D, dentine; *B*, boundary zone (interzonal layer); *E*, perfect enamel; *E*^{1}, imperfect enamel. Magnified 100 diameters.

"In one instance peculiar formations were seen in the cementum. (See Fig. 138.)

"The cementum here exhibits distinct lamellations and scattered cement-corpuscles, with their longitudinal diameters mostly arranged perpendicular to the direction of the lamellæ. The cementum was abruptly interrupted by the dipping downward of the pericementum to the close vicinity of the dentine. In this situation the prolongations of the pericementum were hardened by globular depositions of lime-salts, which were conspicuous by a high degree of refraction.

"This anomaly—altogether different from the process of absorption of the roots of temporary teeth, or that of bone—

Fig. 137.



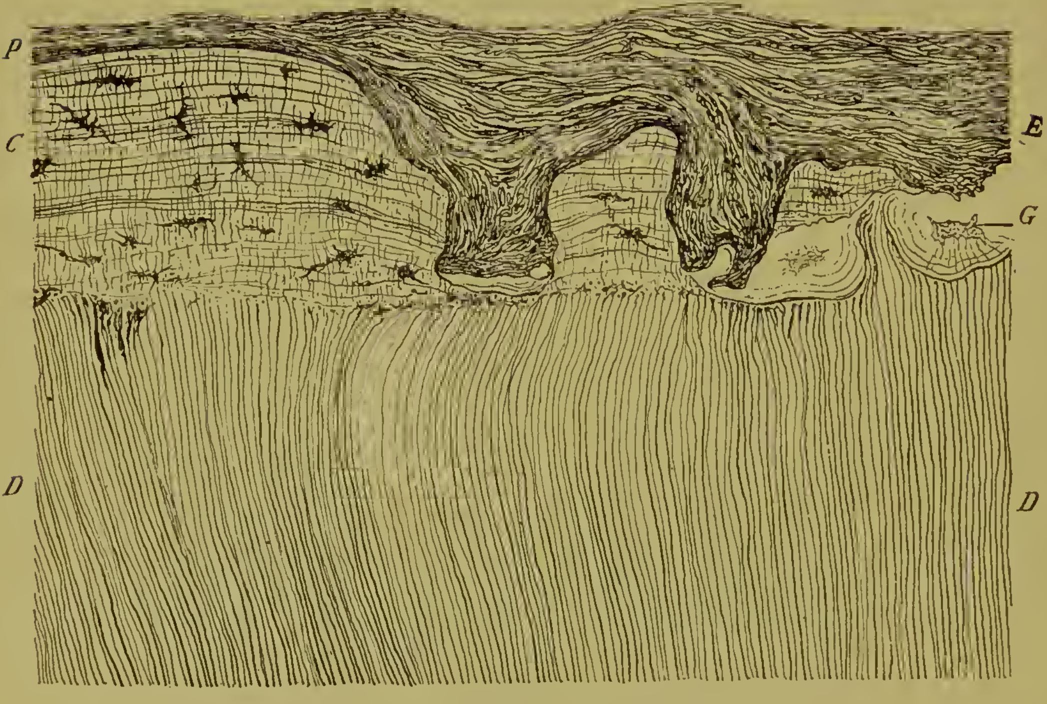
Perfect, Grafted upon Imperfect Enamel.

E^1, irregular and imperfect layer of enamel; E^2, regular layer of enamel; D, dentine; I, interglobular spaces. Magnified 500 diameters.

must have occurred at the time of the development of the cementum, which, as is well known, takes place after the formation of the dentine.

"A remarkable feature in connection with this case was the apparently perfect condition, in the mouth, of the gum and alveolus. In the pericementum the microscope revealed nothing anomalous except a few scattered calcified patches. It is hardly possible that there is any especial connection between this and the morbid process in the enamel, as the enamel is completely formed at a much earlier period than this could have happened. As to the causes which lead to the imperfections in the enamel and other portions of the teeth during the process of development, I will quote as follows from an article on ‘Dentition and its Derangements,’ by A. Jacobi, M.D., 1862. He says,—

FIG. 138.



IRREGULARITIES OF CEMENTUM.

P, pericementum; *C*, stratified cementum with cement-corpuscles; *E*, excavations of cementum filled with pericementum; *G*, globular stratified depositions of lime-salts; *D*, *D*, dentine. Magnified 100 diameters.

“ ‘The enamel of the teeth is subject to several anomalies. It may be either defective or discolored. Its defective formation appears either in excavations dispersed over the surface of the tooth, or there are complete furrows or transverse notches around the crown of the tooth, the body being still covered with or entirely deprived of enamel. This atrophy is the result of those severe diseases which the child may have been suffering from during the development of the enamel. Acute exanthems are said to produce the dispersed excavations; acute inflammatory diseases, the furrows; and rhachitis has often been observed to be the cause of the entire absence of the enamel. The incisors of rhachitic children are usually small, appear late, and are very liable to become carious. Acute exanthems are counted among the causes of this anomaly, especially by such writers as classify the teeth with the dermal tissue. Smallpox is related to produce isolated excavations which have a great similarity to the cicatrices remaining after smallpox. To vaccination, also, some have attributed the defective development of the enamel. . . . The mucous membrane of the mouth is very irritable, being accustomed only to amniotic liquor in fœtal life, and to milk in the early stage of extra-uterine existence. Every change in the diet, therefore, the bad quality of the material, or artificial nipples, the use of candy, sucking-bags, or alcoholic beverages, coffee, or stimulants of whatever kind, will act as irritants, producing hyperæmia or inflammation in a more or less severe form. . . . A more severe form is that known by the name of aphthous stomatitis. The superficial layers of the epithelium are not thrown off during the hyperæmic swelling of the mucous membrane, as in erythematous stomatitis, but a real and visible change takes place in the anatomical structure of the follicles. There is a circumscribed, punctated, vascular injection around a follicle which is gradually infiltrated by exudation. The consecutive swelling increases in proportion, the follicles will burst and exhibit a superficial erosion or ulceration, and the adjacent mucous membrane will be sympathetically affected.'

"Edmund Lesser says, 'In the majority of haired men, which means congenital growth of hair all over the face (hirsuties), I hitherto have observed that defects or irregularities of the dental system were present, since not only a number of teeth, but the corresponding alveoli, were missing. In some cases of normal dentures a broadening of the alveolar processes was apparent.'

"Although of epithelial origin, the enamel-organ is of a myxomatous structure, and thus represents a variety of connective tissue. The history of development of enamel (which makes its appearance about the seventh month of fœtal life) is well understood, as far as temporary teeth are concerned, up to the time of birth of the child. Still we know nothing as to the progress of the lateral pegs in laying the foundation of the enamel-organ and the enamel of the permanent teeth. We simply conclude that the process is identical with that of the temporary teeth, in its development during the earliest years of extra-uterine life. Since the imperfections of enamel, as described, are observable upon permanent teeth only, I, without fear of contradiction, venture the hypothesis that diseases of the oral cavity only affecting the epithelial layers, and the pegs derived therefrom, must cause these defects. Such diseases occur in the oral cavity of young children, under the headings of inflammation (stomatitis), from many causes, leading to the formation of blisters, ulcers, and abscesses. Growth of mildew (so-called thrush) is known to be a fertile source of both such superficial and deep-seated disturbances.

"Acute exanthems, which sometimes spread to the mucous membrane of the oral cavity, undoubtedly play an important part in causing inflammation of the enamel-organ, which results in producing defective enamel.

"We can appreciate the probability that inflammation will partially destroy either the original epithelia or the enamel-organ derived therefrom, and thus be the direct cause of defective enamel. A simple obliteration of a number of blood-vessels which freely surround this organ would suffice so to interfere with its proper function as to diminish the amount of lime-salts deposited; the enamel-prisms in such case might develop normally as to size, but show deficiency in calcification. If, with the inflammation and obliteration of blood-vessels, hemorrhage takes place into the enamel-organ, or effusion of hæmoglobin should occur, pigmentation of the deficiently calcified prisms would become intelligible.

"We can realize that the medullary tissue giving rise to enamel-prisms will, in consequence of inflammation, be so altered or misplaced that the outcome would be imperfect, incomplete, or devious prisms. As I showed in 1885 that the formation of enamel takes place in the shape of layers for the crown and layers for the neck, we may grasp the possibility that the earliest crown-layers may be fully and regularly developed, while the last crown-layers are interfered with and become defective. Should, therefore, an inflammatory process start at the time of the appearance of the earliest crown-layers, and soon abate, the enamel nearest the dentine will be found imperfect. If the inflammatory disturbance continues for a long period, the result will be a thin and incompletely calcified layer of enamel. Should portions of the enamel-organ be completely destroyed by suppuration, entire absence of enamel at such points will be the result. A number of so-called miliary abscesses in the enamel-organ will lead to a porous or 'pitted' enamel. A limited number of somewhat larger abscesses would cause larger holes or pits, or possibly the entire enamel-organ might be destroyed, leaving the dentine entirely unprotected.

"In all the cases of teeth with defective enamel that I have examined, the dentine has been found fully developed and perfectly calcified, with the exception of quite numerous interglobular spaces. These appear in the dentine at the same period of development during which the enamel-organ was affected. This positively indicates the disease or diseases which caused the production of imperfect enamel to have been local rather than general, as has been supposed by some pathologists."

CHAPTER XVII.

DEVELOPMENT OF CEMENTUM.*

Our researches into the history of the development of the teeth extend over a period of eight years, and a large collection of specimens has been at our disposal. Nevertheless, until recently, we hesitated about saying anything upon this topic, as none of the specimens of which we were then possessed revealed anything of interest concerning the development of cementum. This tissue, in human beings, is developed after birth, when the root and its dentine have been fully formed. We know that at the time of birth only the crowns of the temporary teeth are present, but there is no trace of the roots. At what time the tissue in question begins to appear in the human subject, we are unable to state. The only specimens at our disposal, in which the question of the development of the cementum could be studied, were obtained from the lower jaw of a kitten about six weeks old. As the course of development of dentine and enamel is almost identical in cats and men, we feel justified in the assumption that the formation of cementum is likewise the same in both. We are the more confident because of the knowledge that the development of bone exhibits the same features in cats as in men, and because, as is well known, cement is nothing but bone-tissue.

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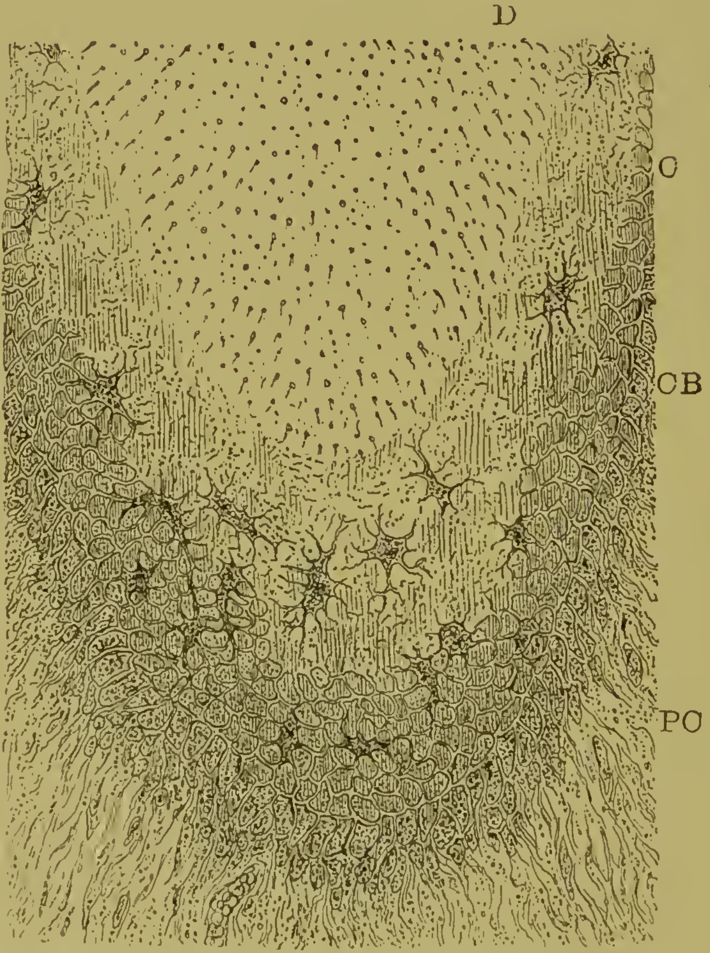
* "Contributions to the History of the Development of the Teeth," by C. Heitzmann and C. F. W. Bödecker. *The Independent Practitioner*, vols. viii, ix.

Fig. 139.



Apex of the Root of a Temporary Tooth of a Kitten Six Weeks Old. Vertical Section.

D, dentine; *C*, cementum, in part thoroughly calcified, and partly made up of medullary corpuscles: *CB*, basis-substance of the cementum, composed of medullary corpuscles: *PC*, pericementum. Magnified 200 diameters.

In the above-mentioned specimens, taken from a kitten six weeks old, we observed both the temporary and permanent teeth in place. The temporary teeth were fully developed and their roots perfect, whereas the permanent teeth only exhibited a small cap of dentine and enamel over the papilla, corresponding to a human fœtus between the seventh and eighth months of intra-uterine life. Both the dentine of the crown and that of the root, especially of the latter, were partly absorbed, and they exhibited bay-like excavations, which were filled with multinuclear protoplasmic masses.

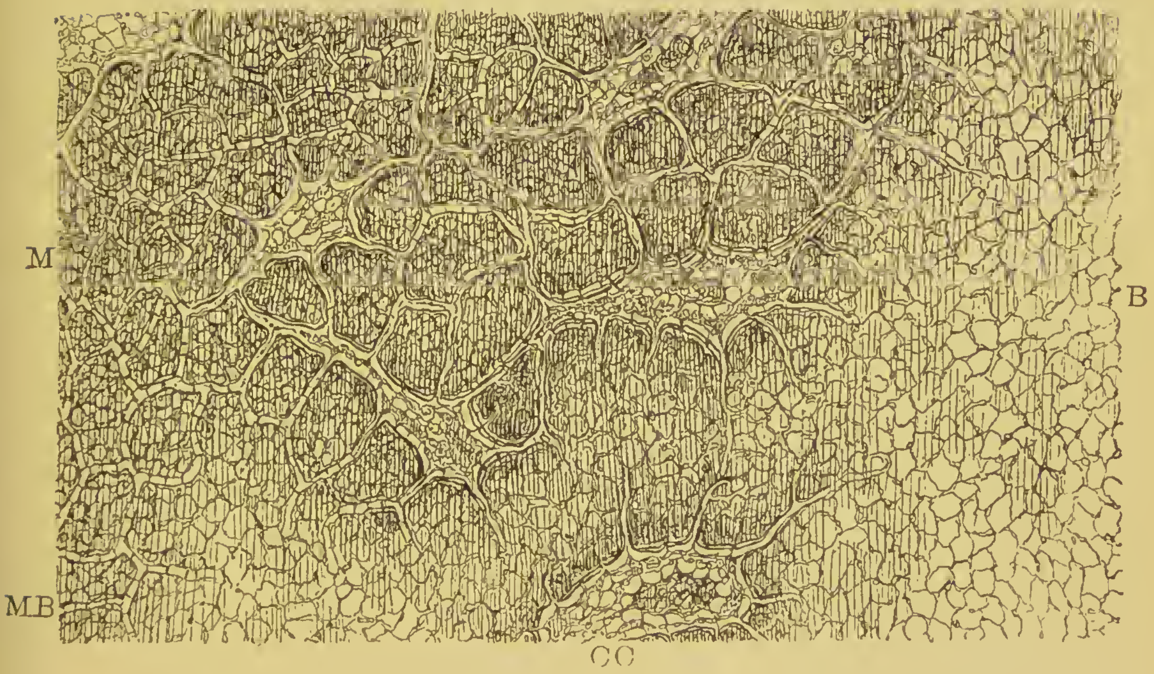
The cement at the cervix of the teeth in cats is a comparatively narrow formation, made up, as in the teeth of men, of delicate spindles arranged perpendicular to the longitudinal axis of the root, between which spindles we observe no cement-corpuscles. This layer is evidently developed from spindle-shaped medullary corpuscles, of which a whole row is visible in the neighboring pericementum. A direct calcification of these medullary corpuscles leads to the formation of the cementum of the neck. Farther down, the cementum becomes broader by the addition of a row of medullary corpuscles greatly varying in size, and without distinct lines of demarcation between them. With lower powers of the microscope their protoplasm appears finely granular; with high powers, however, a distinct reticulum is recognizable, the same as in all protoplasmic formations. Toward the dentine the medullary corpuscles assume a high grade of refraction, indicative of a deposition of lime-salts, which latter have been removed by the treatment with the chromic-acid solution. The boundary-line between the dentine and cementum is nowhere distinctly marked. Still farther down toward the apex of the tooth scanty cement-corpuscles make their appearance, invariably surrounded by a number of finely-granular medullary corpuscles, without any marked territorial formation around each bone-corpuscle. Nearer to the apex the cementum becomes very broad, exhibiting a number of cement-corpuscles. Here this tissue is fully developed around the dentine, but is yet in the process of formation at the periphery of the root. The latter portion plainly reveals the manner in which the cementum is developed.

Like all the tissues of the body, including the dentine and the enamel, the cementum arises from medullary tissue. In this respect cementum and bone-tissue show a striking likeness. The medullary corpuscles from which bone-tissue arises bear the name of osteoblasts, and should any one desire to give a special name to the formers of the cementum, that of cementoblasts should be admissible. These corpuscles become the seat of a deposition of lime-salts before any cement-corpuscles are conspicuous. We observed that the previously-calcified medullary corpuscles are decalcified, and after a second calcification some of them remained unchanged, exhibiting an angular shape characteristic of bone- and cement-corpuscles. This stage, however, still represents an incomplete form of cementum. Lastly, another decalcification of the medullary corpuscles takes place, and this time distinct groups of medullary corpuscles become visible, the centers of which are occupied by the cement-corpuscles, and in this manner the territories of the cementum as well as those of bone-tissue arise. After calcification of the medullary corpuscles has been accomplished, neither the medullary corpuscles nor the boundary-lines of the territories are conspicuous; but when calcification is incomplete, both the medullary corpuscles and the territories are easily recognizable.

With high powers of the microscope we more readily observe the manner in which the cementum is developed. As long as this tissue is imperfect, and not fully calcified, a number of the medullary corpuscles assume a certain degree of refraction which marks partial calcification, whereas some of the medullary corpuscles retain their protoplasmic nature, and thus represent the cement-corpuscles. Nearer to the dentine the medullary corpuscles are arranged in clusters, in the center of which we observe the cement-corpuscles. As a rule, each cement-corpuscle is surrounded by a number of medullary corpuscles representing a territory. Not infrequently a territory is indistinctly defined. This is the case wherever the cement-corpuscles are separated from each other by a single row of medullary corpuscles only, or where the deposition of lime-salts has been completed, whereupon both the medullary corpuscles and the boundary-lines of the territories are lost to sight. (Fig. 140.)

The question arises, How are the offshoots of the cement-corpuscles formed? In order to understand this process, we must bear in mind that the medullary corpuscles, even when incompletely calcified, exhibit the reticular structure characteristic of all protoplasmic formations. They greatly vary in size, and are separated from one another by light rims, which invariably appear traversed by delicate conical offshoots. It is obvious that the offshoots are formations of living matter, serving for the interconnection of all medullary corpuscles. Whenever lime-salts are deposited in the meshes of the reticulum of the medullary corpuscles, the interstices between them remain free from such a deposit. The conical offshoots between the medullary corpuscles coalesce at the centers of the latter into a filament of living matter,—the offshoot of the bone- or cement-corpuscle. Such a delicate offshoot remains interconnected by the lateral filaments running into the reticulum of the medullary corpuscles, the same as is the case with dentine- and enamel-fibers. Even where the calcification of the medullary corpuscles has assumed its highest degree, and where all boundary lines between them have disappeared, the reticulum in the basis-substance remains unaltered, and plainly visible with a good immersion lens, without the addition of any reagent.

Fig. 140.



Cementum in the Process of Formation of a Temporary Tooth of a Kitten Six Weeks Old.

M, medullary corpuscles incompletely calcified, but still recognizable; *MB*, medullary corpuscles thoroughly calcified in parts and transformed into basis-substance; *CC*, cement-corpuscles partly lying in a completely-calcified basis-substance, and partly occupying the centers of groups of medullary corpuscles, the so-called territories; *B*, basis-substance. Magnified 1200 diameters.

The results of our researches concerning the history of development of the cementum of the temporary teeth of a kitten six weeks old are as follows:

I. The cementum arises from medullary tissue, the same as bone- and all other tissues of the body.

II. The medullary corpuscles first become the seat of a deposition of lime-salts before any cement-corpuscles are visible.

III. The lime-salts are dissolved and redeposited again in the medullary corpuscles, which are arranged irregularly around the cement-corpuscles, the latter, however, remaining free from calcareous infiltration.

IV. Still later the medullary corpuscles are arranged in groups, the centers of which are the cement-corpuscles, the sum total furnishing the territories around the cement-corpuscles.

V. The offshoots of the cement-corpuscles are filaments of living matter, originating from the bridges traversing the interstices between the medullary corpuscles.

VI. The reticular structure of the original medullary corpuscles is preserved in the basis-substance even after the completion of the calcification of the latter, and the disappearance of the original medullary corpuscles.

The development of the roots of the temporary as well as the permanent teeth has been carefully studied, as far as naked-eye appearance goes, by C. N. Peirce. The illustrations published by him I have copied in the chapter on "Faulty Development," Fig. 120, page 196. My rather limited knowledge of this topic will excuse my reference to an author known to be reliable.

CHAPTER XVIII.

THE DEVELOPMENT OF TEETH IN EMBRYOS AFFECTED WITH RHACHITIS.*

Among the numerous embryos whose teeth the writers have examined, there were three affected with so-called congenital rhachitis. One of these was a seven-months' fœtus, another seven months and a half, while the third was eight months old. Macroscopically the two former did not exhibit any symptoms of rhachitis, and it was only upon microscopical examination of the jaw-bones that we were enabled to recognize the morbid process, whose characteristic feature is a new formation of hyaline cartilage in the place of bone-tissue. The trabeculæ of the cancellous bone-tissue were scantier, and the bone-corpuscles within them were much larger, than those in normal bone-tissue. In many places, however, hyaline cartilage was present instead of bony trabeculæ, and in the medullary spaces between them. The cartilage-corpuscles often were of a brown color, caused either by previous hemorrhage or by a new formation of blood-corpuscles and hæmoglobin. The third fœtus, which was eight months old, showed the symptoms of congenital rhachitis in such a degree that all bone-tissue throughout the body was lacking, and only in the lower jaw were found a few trabeculæ. This fœtus was delivered by a healthy woman, who, during her pregnancy, for a number of months furnished dogs, cats, and rabbits with soup, meat, bread, and vegetables, mixed respectively with lactic acid, for the purpose of artificially producing rhachitis and osteomalacia in these animals. These experiments were made by Carl Heitzmann (see "Microscopical Morphology," 1883) and proved to be successful. Dogs and cats, treated with lactic acid soon after birth, became rhachitic, and treated with lactic acid for several months in succession, became affected with osteomalacia.

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* "Contributions to the History of Development of the Teeth," by Carl Heitzmann and C. F. W. Bödecker. *Independent Practitioner*, vols. viii and ix.

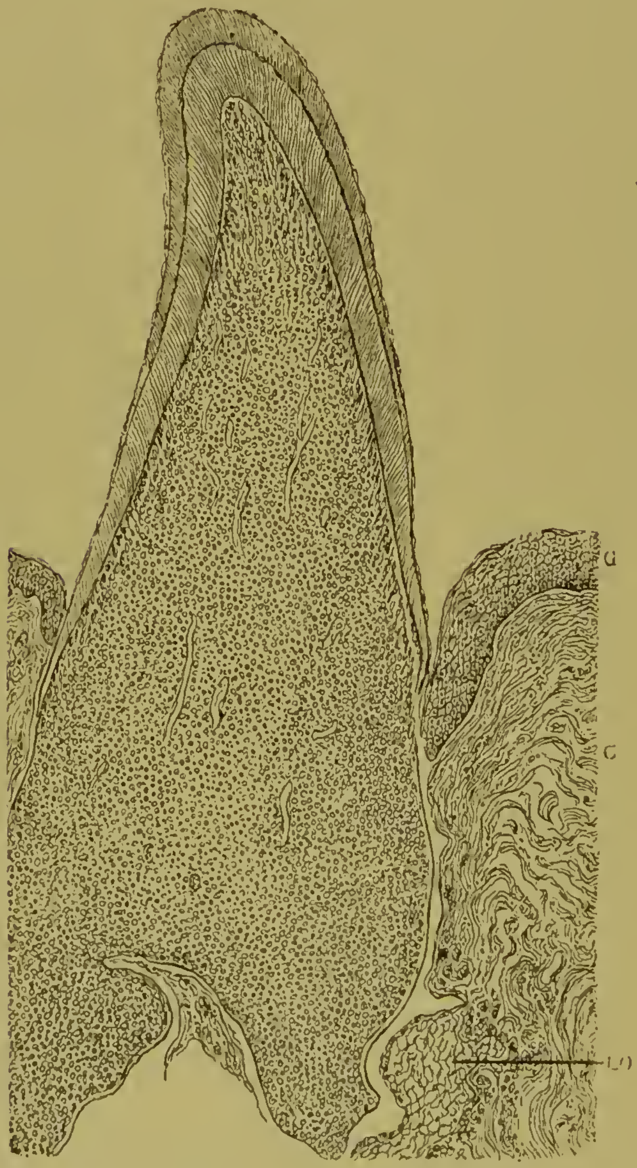
The woman who gave birth to this fœtus was healthy during pregnancy, and remained so after delivery. The fœtus, on the contrary, died shortly after birth, from intracranial hemorrhage caused by pressure during labor, on account of the complete absence of cranial bones.

The abnormal occurrences in the teeth of these three rhachitic embryos were so striking and so numerous that we made an attempt to arrange them under a number of headings, being aware of the fact that different chronic ailments both of a mother and of a fœtus, more especially rhachitis of the fœtus, reflect on the growth of the teeth, and leave marks in the shape of transverse grooves or furrows upon them.

I. Premature Eruption of Ill-developed Teeth, found in the lower jaw of a rhachitic fœtus, seven months old. (See Fig. 141.)

This tooth had reached a stage of development corresponding to about the seventh month of intra-uterine life, but had grown above the level of the gum, and was plainly visible to the naked eye. This specimen helped to settle a mooted question concerning the origin of Nasmyth's membrane,—the cuticle of the tooth. The writers observed that the flat epithelial layer covering the summit, and the dentine at the deeper portion of the tooth, is a direct reduplication of the flat epithelial layer of the gum. The papilla is moderately supplied with blood-vessels,

Fig. 141.



Premature Eruption of a Lower Incisor of a Rhachitic Fœtus, Seven Months Old.

G, gum; *C*, fibrous connective tissue; *EO*, myxomatous enamel-organ. Magnified 50 diameters.

and is of a markedly myxomatous structure, especially at its lower part, which appears lobulated. It is bordered by a structureless layer at its lower portion, which we consider a normal feature, and which is always present previous to the appearance of odontoblasts. The gum is composed of a loose, delicate, fibrous connective tissue. At the right side of the specimen, near the lower portion of the papilla, there appears an isolated layer of myxomatous tissue, which extends below the papilla, bearing the characteristics of the enamel-organ. Its outer periphery shows a number of buds or nests, which are the offspring of the external epithelium.

II. Double Papillæ.—In the same fœtus the writers observed two papillæ of lower bicuspids, which at their bases were united into one continuous broad mass, whereas higher up there was seen a cancellous bony structure, separating the papillæ, which proves that they belonged to two separate teeth. The structure of these papillæ was markedly myxomatous, similar in appearance to that of the papillæ of pig's teeth. The enamel-organ appeared to be in full development, being lined by the internal epithelium, which was broken up into medullary tissue, and an external epithelium broken up into epithelial nests. Along the internal epithelium peculiar folds and indentations are visible, which the writers propose to describe later on. No trace of dentine or enamel was visible upon these germs.

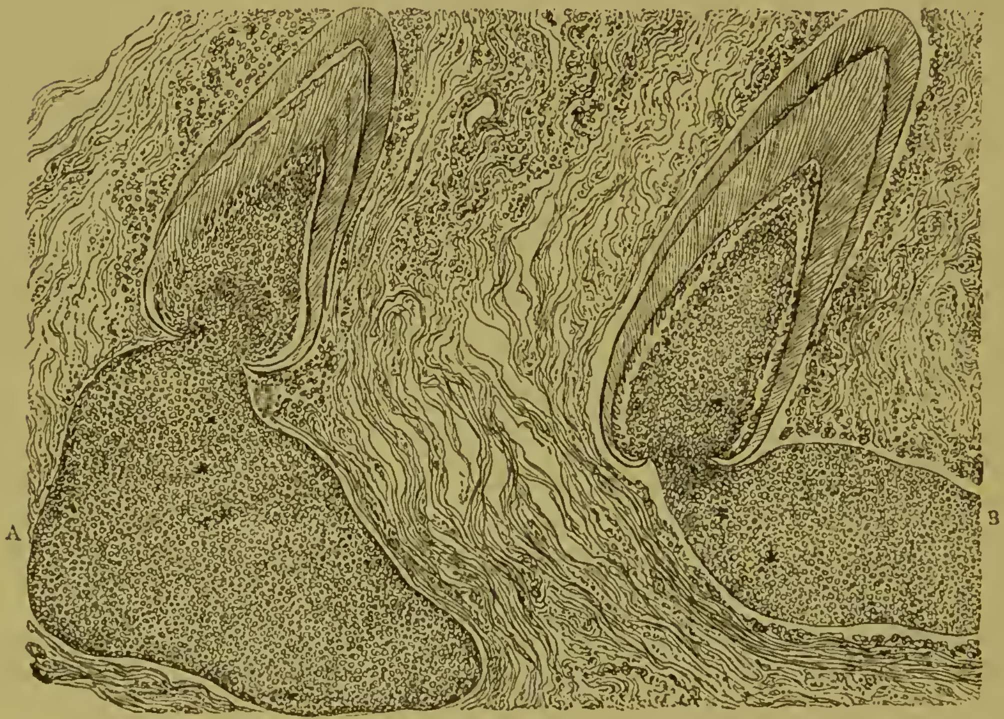
III. Dwarf Teeth.—In the rhachitic fœtus which was seven and a half months old, the writers met with minute teeth which were in a stage of development corresponding to the age of the fœtus. (See Fig. 142.)

The papillæ are of very irregular shape, being partly blunt, partly elongated, and sharply marked by a constriction at the place corresponding to the neck of the future tooth. Above the neck the papillæ are of the usual lancet or myrtle-leaf shape, exhibiting along their borders either odontoblasts or rows of medullary corpuscles, and showing comparatively few blood-vessels. The dentine is curved around the constriction in a marked degree, surrounding the neck of the tooth like a cap. Its canaliculi are wide, but without pathological features. The enamel is likewise to be considered normal, but the enamel-organ is missing in all of these specimens, which indicates that the myxomatous reticulum was exhausted. The external epithelium only shows its presence by small epithelial nests and buds along the already-formed enamel.

A peculiar feature of both the papilla and the surrounding connective tissue is the presence of rusty-brown, needle-shaped crystals of hæmatoidin, sometimes clustered together in numerous masses. These are the result of a previous hemorrhage, although it is not explicable how they appear in the papilla, where the blood-vessels are extremely scanty and just in the process of formation.

IV. Malformations and Malpositions of the Enamel-Organ.—In the teeth of a rhachitic fœtus we not infrequently meet with enamel-organs markedly differing from normal ones, the difference mainly consisting in the lack of a myxomatous reticulum. This tissue appears in the shape of small, glistening granules, arranged either in the shape of clusters or of an indistinct reticulum. The granules themselves vary somewhat in size, and among them larger granular corpuscles may be seen, which, without any regular arrangement, are yet entitled to the name of nuclei. The meshes of this irregular reticulum hold an apparently structureless mucoid basis-substance. Besides these irregular formations of the enamel-organ, we sometimes meet with malpositions of it, either in a normal or an anomalous condition. (See Fig. 143.)

Fig. 142.

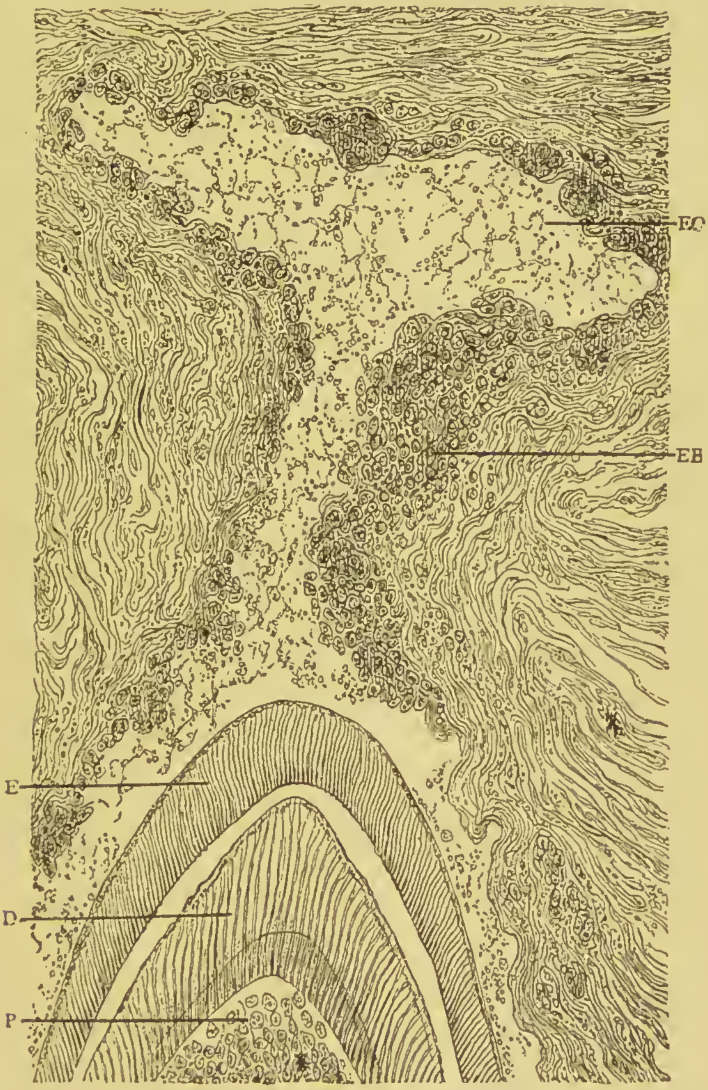


Dwarfed Teeth of a Rhachitic Fœtus, Seven and a Half Months Old.

A, blunt foot-shaped papilla, with a constriction, from which the dentine starts; *B*, elongated narrow papilla, from which grows at an acute angle the tooth, again marked by a constricted neck. Magnified 50 diameters.

In this specimen the enamel-organ is located entirely above a tooth, which is likewise anomalous. It is widened in a horizontal direction, nearly parallel to the outer surface of the mucosa. It extends downward along the newly-formed dentine and along the upper portion of the papilla. It is lined with medullary tissue and with clusters of epithelia, both being derived from the external epithelium, whereas the internal epithelium is com-

FIG. 143.



ANOMALOUS LOCATION AND FORMATION OF THE ENAMEL-ORGAN OF A HUMAN FŒTUS SEVEN AND A HALF MONTHS OLD, AFFECTED WITH CONGENITAL RHACHITIS.

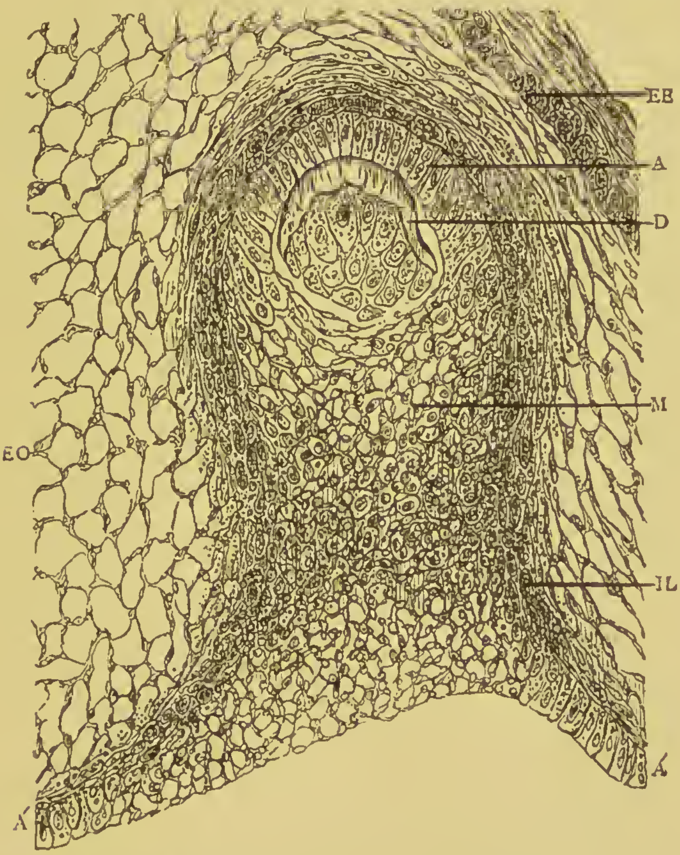
EO, enamel-organ; *EE*, external epithelium; *E*, enamel; *D*, dentine; *P*, papilla. Magnified 100 diameters.

pletely exhausted for the formation of the enamel. The layer of medullary tissue arising from the external epithelium is broad, but short on one side, and narrow and much elongated on the other side of the enamel-organ. The tooth is anomalous not in its size, nor in respect to the stage of development it is in, but on account of its devious papilla, resembling the teeth illustrated in Fig. 142. The specimen was obtained from the same embryo as those illustrated in Fig. 142. The papilla is constricted at the place where the dentine begins, at the neck of the tooth, below which the papilla suddenly widens and produces a bluntly-elongated body of considerable size, composed of medullary tissue, and holding a number of clusters of hæmatoidin crystals, which are also seen in the neighboring fibrous connective tissue. Another misplacement of the enamel-organ is illustrated in Fig. 141, in which it is depicted as located beneath the base of the papilla.

V. Folds, Convolutions, and Reduplications of the Epithelium of the Enamel-Organ.—In both rhachitic embryos from which specimens have been taken, we have encountered in the enamel-organ peculiar formations, which we propose to describe under the above heading. Near the external epithelium, which at the age designated is invariably split up, we have sometimes found concentrically-arranged epithelial nests, or clusters of medullary tissue, imbedded in an otherwise normal myxomatous reticulum. Far more common than these formations, which depend upon a reduplication of the external epithelium, are foldings and convolutions of the internal epithelium. (See Fig. 144.)

The internal epithelium shows, sometimes, simple indentations, which are also observed occasionally in normal teeth of the same stage of development. At other times there is a series of successive convolutions of the internal epithelium. Neighboring this epithelium the myxomatous tissue of the enamel-organ, as a rule, is in a medullary condition, with and without a pronounced intermediate layer. Obviously, such sinuosities correspond to furrows of the enamel-organ, and very probably may cause the ridges and furrows often observed upon this tissue. The highest degree of reduplication of the internal epithelium is sometimes seen, together with apparently isolated buds of dentine, surrounded by and inclosed in a layer of ameloblasts and myxomatous tissue. The dentine consists either of a narrow calcareous rim, or a cap in which we may observe distinct dentinal canaliculi. If the dentinal cap appears as a thin calcified ledge, it is composed of calcified medullary corpuscles, beneath which odontoblasts are perceptible. If the ledge of the dentine is broader and supplied with dentinal canaliculi, we notice close beneath it a layer of medullary corpuscles followed by a layer of odontoblasts which are usually in process of breaking up into medullary corpuscles. It may be possible that such formations are the starting points of the transverse furrows observed upon the labial surfaces of the temporary teeth of rickety children, although these occurrences are far more common on permanent teeth.

Fig. 144.

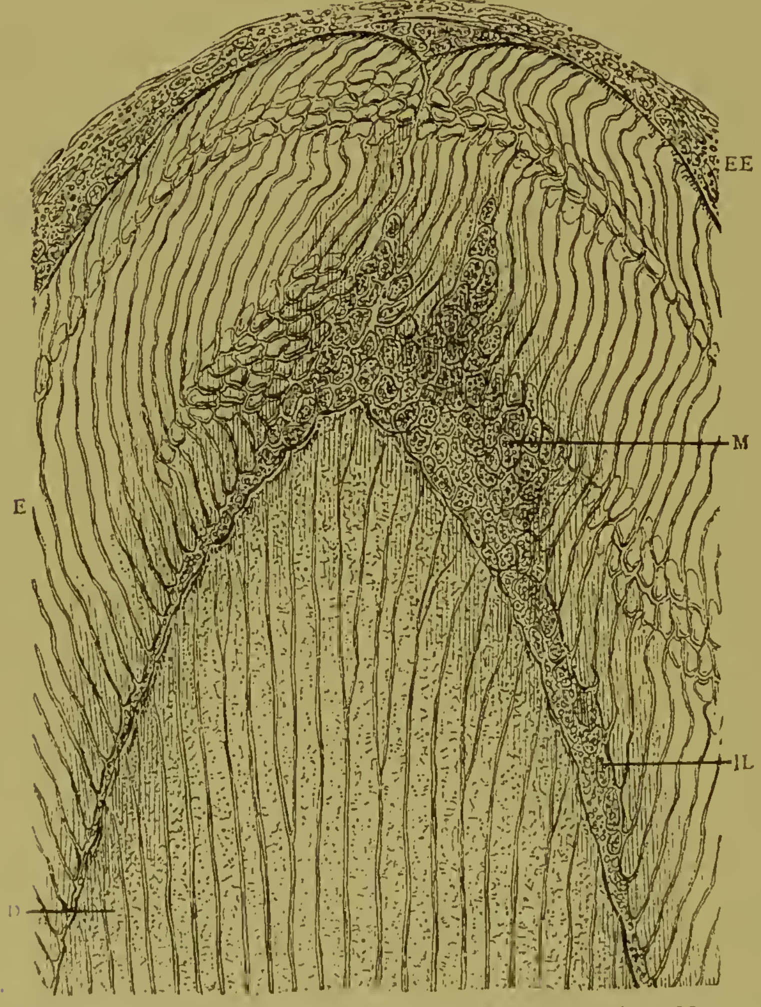


Reduplication of the Internal Epithelium of a Rhachitic Fœtus Seven and a Half Months Old, around a Bud of Dentine.

EO, myxomatous enamel-organ; *EE*, external epithelium; *A*, layer of ameloblasts; *IL*, interstitial layer composed of spindle-shaped elements surrounding the ameloblasts; A^1, A^1, layer of ameloblasts toward an already-formed enamel; *M*, myxomatous tissue approaching the structure of medullary tissue; *D*, dentine with underlying odontoblasts. Magnified 200 diameters.

VI. Anomalies of Enamel.—It is a common feature in teeth of rhachitic children that the interstices between the enamel-prisms are wide, and their tenants, the enamel-fibers, are very distinct, often running a wavy course independent of the contours of the enamel-prisms. The prisms themselves are finely granular, without distinct cross-lines. These features are explained by the evidence of a deficient calcification of the enamel, which allows the cutting of thin sections of the enamel after it has been softened in chromic-acid solution, whereas it is impossible to obtain sections of normal enamel in the same manner. In a rhachitic fœtus eight months old, we have observed in the enamel dark-brown colorations, which are to be considered as

Fig. 145.



Anomalous Enamel of a Rhachitic Fœtus Seven and a Half Months Old.

EE, enamel-organ of medullary character arisen from the external epithelium; *E*, enamel composed of prisms of a markedly wavy course; *M*, cluster of medullary corpuscles,—*i.e.*, non-calcified enamel-tissue; *IL*, interzonal layer filled with medullary corpuscles; *D*, dentine. Magnified 500 diameters.

pigmentations of the enamel-rods. Another feature in the enamel of rhachitic embryos is a markedly wavy course taken by the enamel-prisms,—so much so that in a strictly longitudinal section alternate layers of enamel-prisms appear, some of which are cut longitudinally, while others are transverse. (See Fig. 145.)

Frank Abbott has already drawn attention to the fact that transverse sections of enamel-prisms, alternating with longitudinal sections, are not caused by an interlacing of the enamel-prisms, but by a wavy or devious course of the enamel-prisms themselves, and our specimens have furnished satisfactory proof of the correctness of the latter view.

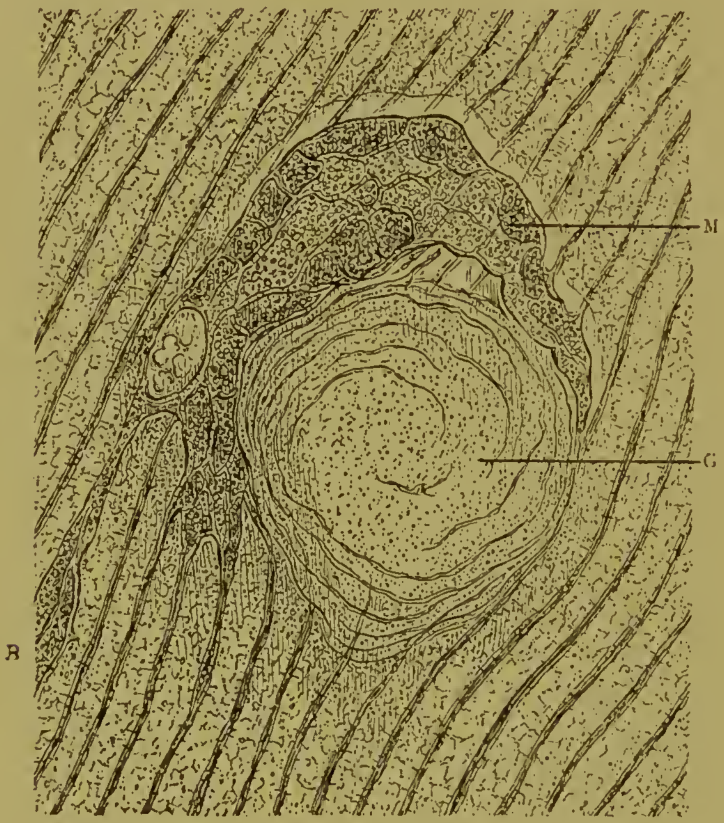
Not infrequently we observe at the summit of the dentine, in the interzonal layer, medullary corpuscles, either arranged in rows or irregularly scattered in the vicinity of the dentine. Such formations scarcely admit of any other interpretation than that the medullary elements, from which the enamel-prisms originate, have not been calcified, but have remained in an embryonal state. (See Fig. 145, *M* and *IL*.)

In specimens from a rhachitic fœtus seven and a half months old, the enamel appeared bordered by a medullary tissue, whose origin could be directly traced from the buds and clusters, the remains of the external epithelium. Here, therefore, our previous assumption, that the external epithelium likewise furnishes material for the increase of the enamel, can be directly proven.

VII. Anomalies of the Dentine.—The dentine of all rhachitic teeth is conspicuous by wide dentinal canaliculi, in which the dentinal fibers and their lateral offshoots are easily discernible. The basis-substance shows a more or less marked reticular structure, without the application of any reagent. In a fœtus eight months old we found peculiar formations of dentine, which evidently are caused by a deficient calcification of this tissue. (See Fig. 146.)

Such spaces send offshoots upward and downward in the dentine, which represent either conically-widened dentinal canals, or broad routes replacing the same. The spaces and their larger branches are filled with medullary corpuscles in all stages of development. Where the space inosculates with dentinal canaliculi, the tenants of the latter are coarse fibrillæ, with spindle-shaped widenings composed of large granules. Both within these spaces and in their vicinity we observe globular formations which exhibit the features of badly-developed secondary dentine, or globular dentine, resembling the structure of the dentine of the so-called pulp-stones, or denticles. Spaces of this description resemble the interglobular spaces of Czermak, but they are more irregular and much larger.

FIG. 146.



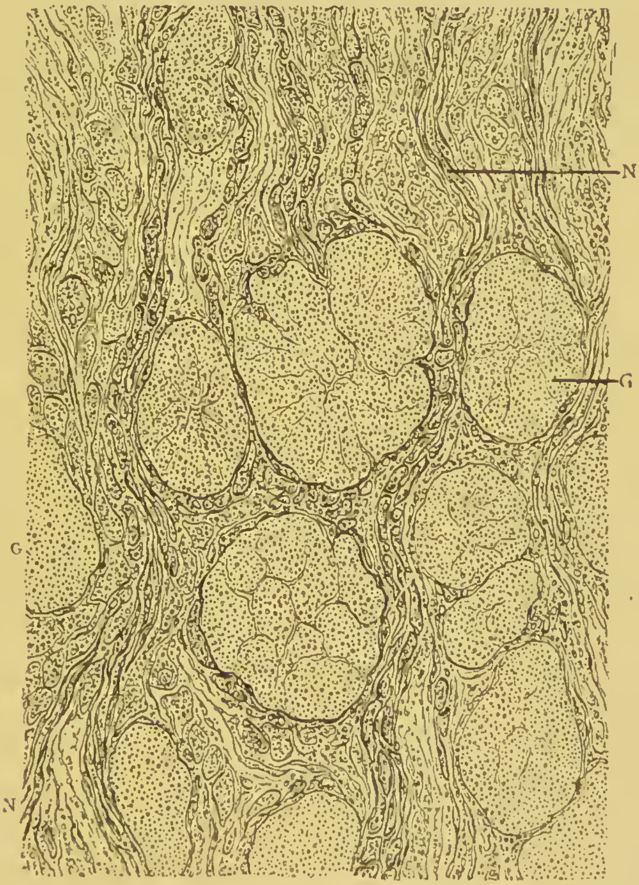
MEDULLARY SPACE AND GLOBULAR MASS IN THE DENTINE OF A TOOTH OF A RHACHITIC FŒTUS EIGHT MONTHS OLD.

M, medullary corpuscles filling a crescentic space in the dentine; *B*, branch of the crescentic space replacing a dentinal canaliculus; *G*, globular, concentrically-striated mass. Magnified 600 diameters.

VIII. Anomalies of the Papilla.—The writers have described and illustrated, in Fig. 142, anomalous papillæ of peculiar shapes. In such papillæ we often observe crystals of hæmatoidin grouped together in clusters, the origin of which must be sought for in an imbibition by the tissue of the coloring-matter of the blood at a very early stage of development. The writers furthermore wish to draw attention to peculiar formations met with in the medullary tissue of the papilla. (See Fig. 147.)

Such globules we have observed only at the summit of the papilla, and in close connection with medullated nerve-fibers. The globules are pale, finely granular, and with either smooth or lobulated contours. Their interior shows faint marks of division, which indicate that the globules have arisen from medullary corpuscles or clusters thereof. We are unable to determine the nature of such corpuscles, which seem to be in relation to newly-forming medullated nerves. All the nerve-fibers seem, however, to run between the globules, although it appears in the drawing as if a bundle of nerves inosculated with a globule. This may be explained by the assumption of a devious course of the nerve-bundle.

Fig. 147.



Globules in the Papilla in a Rhachitic Fœtus Seven and a Half Months Old.

G, *G*, granular globules, partly smooth, partly lobulated; *N*, *N*, medullated nerves. Magnified 600 diameters.

The most interesting feature of such papillæ is that the medullated nerves first appear at the summit of the papilla, whereas the lower portions of the papillæ are free from nerves, and only exhibit scanty capillary blood-vessels. The nerves still appear to be composed of rows of medullated corpuscles, without any trace of the myelin sheath. Whether or not axis-cylinders are present, we could not determine from the longitudinal sections before us. This much is certain,—that the nerves grew independent of the central nervous system; that they were in no connection with already-formed nerves of the central nervous system, and, therefore, that they must have arisen from medullary corpuscles in essentially the same manner as other tissues.

Those who strictly adhere to the doctrine of exclusiveness in embryology—the doctrine that development proceeds from the three original layers—will try in vain to explain such an independent formation of nerves in the middle of connective tissue.

CHAPTER XIX.

THE DENTAL PULP.*

Methods.—The best method of preparing pulp-tissue for examination is to place the tooth, immediately after its removal from the mouth, in an aqueous solution of chromic acid of from one-half to one per cent. strength. To this mixture may be added, every third or fourth day, one or two drops of dilute hydrochloric acid, to hasten the process of decalcification. It is important to use a large quantity of the liquid,—not less than a quart for one tooth or a few,—and to renew the same at least every second or third day. After the teeth have been in the chromic-acid solution a few weeks, the peripheral portion of the dentine will become sufficiently soft to be cut by a razor. When the hard parts of the dentine are reached by the cutting-instrument, the extraction of the lime-salts must again be continued in the manner described above, until the pulp-cavity is reached.

Another method is to split the tooth, as soon as possible after its extraction from the mouth, with a strong pair of excising-forceps. The teeth best adapted for this method are the incisors, cuspids, and bicuspids. By an experienced manipulator the pulps of molars can be extricated from their inclosing walls, but with less success than in the teeth before mentioned. In splitting, put the cutting-edges of a sharp pair of excising-forceps in the longitudinal direction near the apex of a single-rooted tooth, then exert a sharp and quick pressure, when, as a rule, the tooth will split into halves with the pulp-cavity exposed. Immediately moisten the pulp with a solution of chloride of sodium in water, of the strength of about one-half of one per cent., and then remove the pulp. The greatest care must be taken, in picking the fragments of the tooth from the pulp-tissue, to avoid tearing the organ, as tearing greatly alters the microscopical aspect of nerve-tissue. If the pulp is to be stained with carmin, hæmatoxylon, fuchsin, hyperosmic acid, picro-indigo, or chloride of gold, etc., place it in the staining-fluid immediately after its removal from the hard parts of the tooth.

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* "The Minute Anatomy, Physiology, Pathology, and Therapeutics of the Dental Pulp." *Dental Cosmos*, 1882.

Among the reagents mentioned, I have found but one of considerable value,—viz, the solution of chloride of gold of the strength of one-half of one per cent. This reagent may be applied to fresh pulps as well as to very thin sections obtained after hardening in chromic acid. These specimens, however, must, as a matter of course, be carefully washed with distilled water before the chloride-of-gold solution is added. The reagent may be allowed to remain in contact with the specimens for from twenty to thirty minutes, when they should again be washed in distilled water and exposed to daylight. In a few days fresh specimens assume a bright violet color, while sections which have previously been in a chromic-acid solution become brownish-violet. Osmic acid, in solution, one per cent. strong, renders the contours of the constituent tissues, and especially those of the medullated nerve-fibers, more distinct, as it stains the nerve-fat dark green. Both fresh and chromic-acid specimens may be treated with osmic acid. Thin sections do not require more than an hour's exposure to this reagent, while whole fresh pulps may be left in it for two or three hours. Except the ammoniacal solution of carmin, which is known to be excellent for staining certain parts of the tissue, I would not lay stress upon applying any of the other reagents mentioned.

If we wish to examine the pulp, together with the inclosing dentine, or a pulp-stone, the specimen, previously softened by chromic acid, must be imbedded in a mixture of paraffin and wax, which is best done in the following manner. Place the softened tooth in absolute alcohol for about twenty-four hours; then, of rather thick paper, prepare a box somewhat larger than the specimen; warm the imbedding mixture, which consists of about eight parts of paraffin and one of white wax, until it is barely liquid; pour enough of it into the paper box about to half-fill it; then take the specimen out of the alcohol, and as soon as it begins to dry, place it in the paper box and pour over it some more of the paraffin and wax, so as to cover it completely. Care must be taken not to have the imbedding mixture too hot, as it may injure the specimen. The latter, after the mixture has become sufficiently hard, is ready for cutting, when very thin sections can easily be obtained. To-day imbedding in celloidin is used almost exclusively.

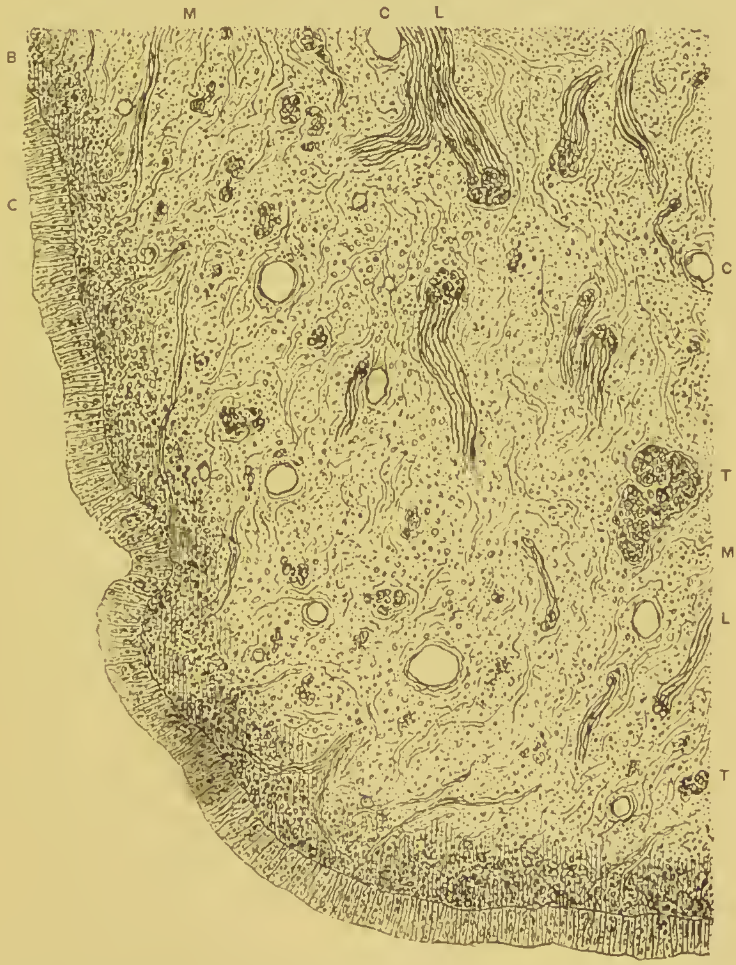
If a fresh pulp is thin enough, it may, immediately after its removal from the split tooth, be transferred to the slide, with the addition of an indifferent fluid, such as the solution of chloride of sodium, etc. But a slight and careful pressure upon the cover is necessary in order to spread fresh specimens. The fresh pulps of lower incisors, being the thinnest, are the best adapted for examining the system of blood-vessels. In a short time, however, they fade away, and the specimen becomes unfit for preservation. Isolated pulps may be placed between two plates of velvet cork, and thus cut into thin sections with the razor. I would recommend chemically-pure glycerin as the best preserving-fluid for pulp-specimens.

The Minute Structure of Pulp-Tissue.—The dental pulp represents the remains of the former dentine papilla, and occupies the central cavity of the tooth. It is richly supplied with blood-vessels and nerves, which enter the pulp-chamber at the apex of every root through one or more openings. The tooth for its supply of nourishing material depends upon the pulp and the pericementum. In many instances a tooth, after the death of the pulp, may be retained in its place for years, deriving its blood-supply from the pericementum only.

If we examine a thin longitudinal or transverse section of the pulp with low powers of the microscope (200 diameters), we recognize a large number of blood-vessels and bundles of medullated nerve-fibers. The majority of these blood-vessels are capillaries; the veins are less numerous, and arteries are scarce. Often we find in a pulp only one arteriole: frequently arterioles lie in the midst of the medullated nerve-bundles. The medullated nerve-bundles mostly run in a longitudinal direction, but not infrequently we observe smaller bundles, or single medullated nerve-fibers, to diverge from the longitudinal direction, and to run obliquely through the pulp-tissue.

In transverse sections of the pulp we meet with arteries, veins, and capillaries, the first cut across, the others distributed in all directions. The bundles of medullated nerve-fibers are seen most distinctly in transverse sections. They often hold in their interstitial tissue capillary vessels and arterioles, which also appear in transverse sections. In very thin sections it often hap-

Fig. 148.



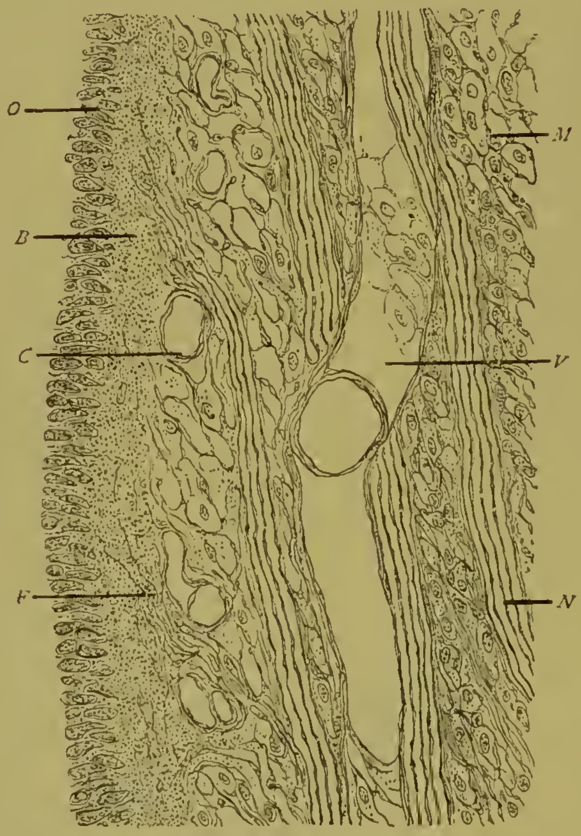
Normal Pulp in Transverse Section, Stained with Chloride of Gold. From a Molar of a Youth Sixteen Years Old.

O, layer of odontoblasts, arranged in rows of medullary corpuscles; *B*, granular layer; *M*, *M*, myxomatous, erroneously termed "adenoid," tissue; *C*, *C*, capillary and venous blood-vessels; *T*, *T*, bundles of medullated nerves in cross-section; *L*, *L*, bundles of medullated nerves in longitudinal section. Magnified 75 diameters.

pens that the nerve-fibers fall out, and then we see a roundish empty space bounded by the sharply-defined external perineurium. The absence of an endothelial coat renders such spaces easily recognizable in distinction from blood-vessels. (See Fig. 148.)

The main mass of the pulp, as seen with low powers, is composed of a delicate fibrous reticulum, containing a large number of bright corpuscles. Longitudinal sections in many instances exhibit delicate fibrous bundles scattered throughout the reticular structure of the pulp, mostly in the neighborhood of large blood-vessels and nerve-bundles. The fibrous reticulum, in the crown portion, is evenly distributed; in the root-portions, on the contrary, it is much elongated. Pulps composed of a fibrous connective tissue only, are rather exceptional, and, as it seems,

FIG. 149.

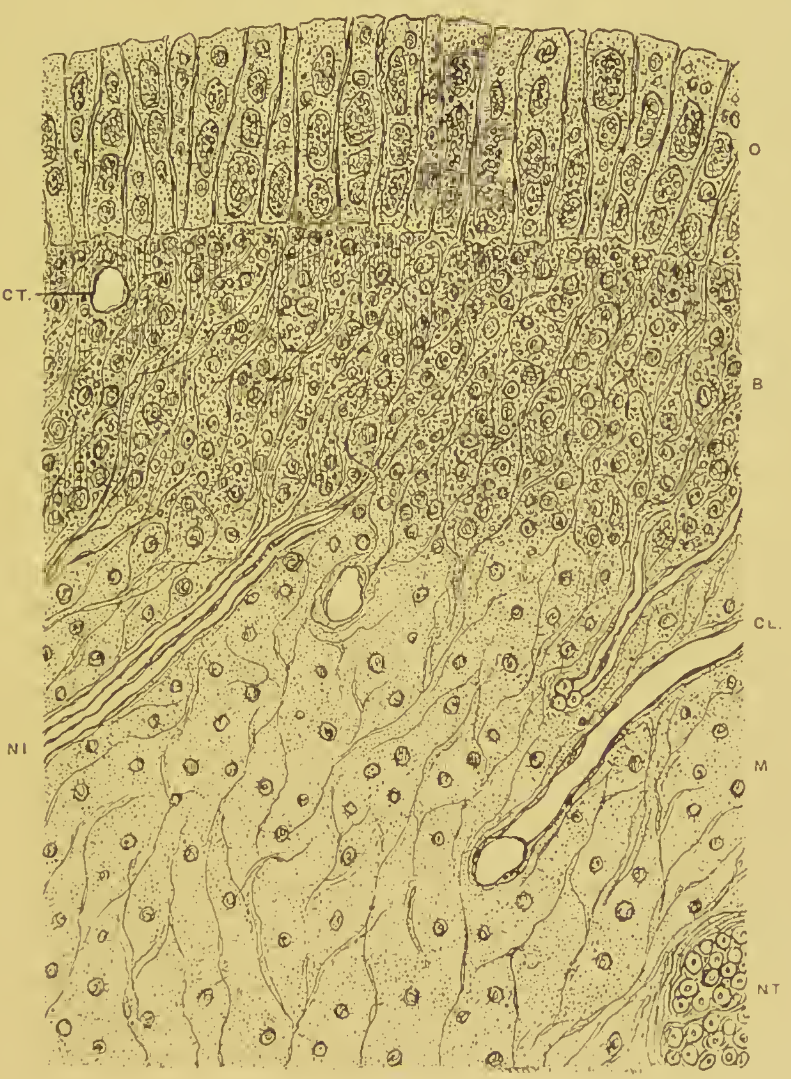


SEGMENT OF THE PULP OF A FIRST MOLAR TOOTH. LONGITUDINAL SECTION.

M, myxomatous connective tissue; *V*, vein; *C*, capillary blood-vessel; *N*, bundle of medullated nerve-fibers; *F*, terminal non-medullated nerve-fibers; *B*, protoplasmic layer, containing the terminations of the nerves; *O*, layer of medullary corpuscles in rows, termed odontoblasts. Magnified 200 diameters.

their occurrence is without any relation to the age of the person. They are always the result of morbid processes. Toward the outer surface of the pulp the reticular structure is, as a rule, denser than in the middle portions. This peripheral part is surrounded by a wreath of elongated formations arranged in a radiating manner all around the pulp,—the so-called "odontoblast layer." (See Fig. 149.)

Fig. 150.



Normal Pulp in Transverse Section, Stained with Chloride of Gold. From a Molar of a Youth Sixteen Years Old.

O, layer of odontoblasts, arranged in rows of medullary corpuscles; *B*, granular layer; well-developed myxomatous lymph-tissue; *M*, myxomatous lymph-tissue, basis-substance still protoplasmic; *CL*, capillary blood-vessel in longitudinal section; *CT*, capillary blood-vessel in transverse section; *NL*, bundle of medullated nerves in longitudinal section; *NT*, bundle of medullated nerves in transverse section. Magnified 500 diameters.

Higher powers of the microscope (500 to 600 diameters) reveal a minute reticular structure, consisting of delicate fibers or anastomosing protoplasmic cords, with very small oblong nuclei at their points of intersection. The mesh-spaces inclosed by this reticulum either look pale and finely granular throughout, or there is, besides the pale granular substance, a bright yellowish body, either homogeneous or granular, of the size and aspect of a nucleus. The number of the latter formations varies greatly in different pulps. Where bundles of a fibrous tissue traverse the reticulum, there the latter blend with the former. In the fibrous bundles, besides the delicate fibrillæ, we see scanty and small oblong nuclei. (See Fig. 150.)

As mentioned before, the fibrous connective tissue prevails at the periphery of the larger blood-vessels and nerve-bundles. In transverse sections the latter invariably exhibit a distinct fibrous sheath containing oblong nuclei,—the so-called external perineurium. The nuclei imbedded in the sheath do not project above the level of the sheath, as is plainly observable on empty ones where the fibers have fallen out, while the endothelia of blood-vessels of any description invariably protrude toward the inclosed space, thus affording an excellent means of distinction between blood-vessels and empty nerve-sheaths.

The arteries are characterized by the presence of a layer of smooth muscles, outside of which is seen a slight fibrous coat. The layer of smooth muscles necessarily thickens the walls of the blood-vessels, thus rendering them easily recognizable in transverse sections. The veins, marked by their large caliber, their scanty muscle-fibers, and a fibrous coat, are usually filled with blood-corpuscles. The capillaries are composed of a single endothelial layer, which is separated from the adjacent reticulum by an extremely delicate light rim. They are found either empty or containing a few blood-corpuscles.

In longitudinal sections the medullated nerve-fibers show the well-known fluted double contour of considerable refraction (the sheath of Schwann). Inside of this is the myelin (nerve-fat) concealing the central axis-cylinder. Schwann's sheath exhibits delicate oblong or spindle-shaped nuclei, and external to this we observe a very delicate layer of fibrous connective tissue,—"the internal perineurium." In cross-sections of the nerve-bundles a more or less circular group of medullated nerve-fibers is seen, each of which in its center exhibits the axis-cylinder in the shape of a roundish, glistening dot, the single nerve-fibers being separated from one another by the delicate internal perineurium. Not infrequently capillary and arterial blood-vessels are met with between the nerve-fibers which, at the periphery of the bundles, blend with the nucleated sheath of the external perineurium.

As to lymphatics of the pulp, I can say that in some specimens I have seen branches of vessels of the size of veins without an adventitial coat, and composed of large, flat, slightly-protruding endothelia. These vessels I believe to be lymphatics, as they contained a finely-granular coagulated albumen, scanty granular corpuscles, and a very limited number of blood-corpuscles. As to the distribution of lymphatics, I must abstain from positive statements.

It seems that pulps containing calcareous globules afford the best opportunity for the study of the lymph-vessels, owing to their dilated condition. Fig. 151 is taken from the coronal portion of such a pulp, and beautifully shows the relation of the lymph- and blood-vessels to the bundles of medullated nerves.

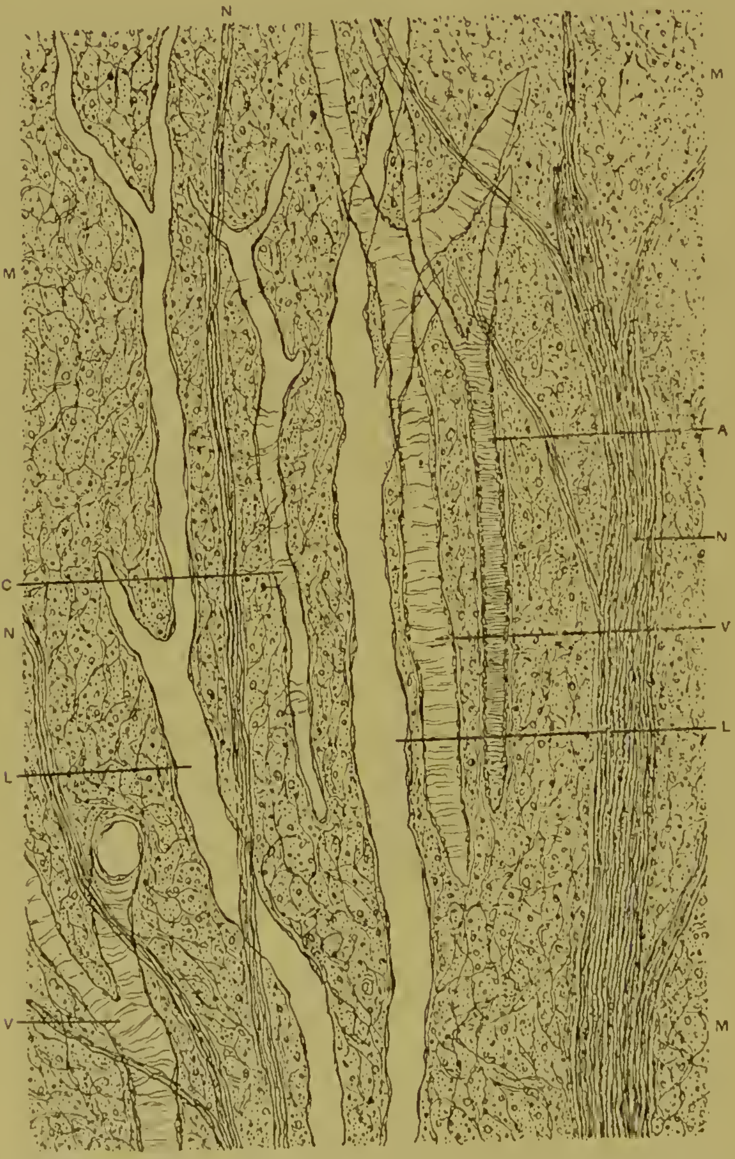
At the periphery of the pulp the delicate reticulum constituting the pulp-tissue is very dense, and its small meshes are supplied with numerous corpuscles looking like nuclei. In this layer we meet with only narrow capillary blood-vessels. The outer surface of this layer is bounded by radiating rows of shining corpuscles of the size and appearance of nuclei. These rows are separated from one another in a longitudinal direction by light rims, in which, frequently, delicate fibrillæ may be observed.

In chromic-acid specimens stained with carmin, or, still better, in those treated with chloride of gold, high powers (1000 to 1200 diameters) reveal an extremely minute reticular structure pervading all formations of the pulp-tissue.

The formations at the periphery of the dental pulp, which were termed "odontoblasts" by J. Tomes, and which by some observers have been considered as epithelium-like formations, under high amplifications exhibit the following:

Longitudinal bodies, somewhat resembling epithelia, border the pulp in a radiatory direction. Such a field may appear in the shape of a finely-granular protoplasm or basis-substance, in which there are imbedded oblong nuclei in varying numbers. The nuclei exhibit coarse granules and a dense reticulum of living matter, while the elongated fields inclosing the nuclei exhibit pale granules and a delicate reticulum. Between these latter formations a narrow light rim is seen, wherein we observe sometimes broad, sometimes delicate, fibrillæ in connection with the reticulum of neighboring formations, accompanied by delicate conical offshoots, which penetrate the surrounding rims at right angles. In many instances these formations between the odontoblasts may be traced into the dentinal fibers, lodging in the middle of the dentinal canaliculi.

Fig. 151.



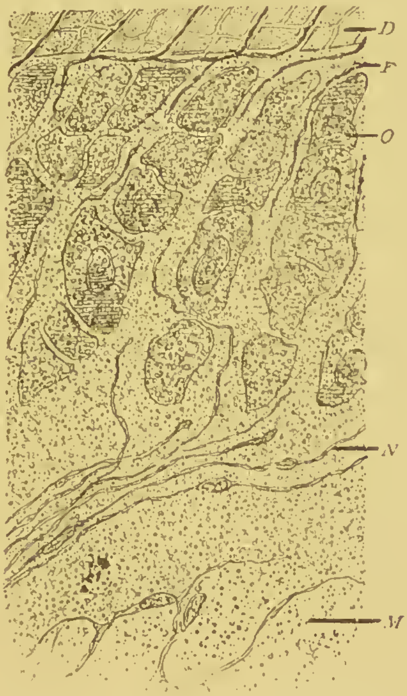
Vessels and Nerves of the Crown of a Pulp containing Calcareous Globules.

N, *N*, large and small bundles of medullated nerves; *A*, arteriole; *V*, *V*, veins; *C*, capillary blood-vessel; *L*, *L*, lymph-vessels; *M*, *M*, myxomatous lymph-tissue. Magnified 200 diameters.

It is evident, from what I have seen, that the odontoblasts furnish the matrix for the basis-substance of the dentine, whereas the dentinal fibers, being formations of living matter, originate *between* the odontoblasts. (See Fig. 152.)

In specimens of a nine-months' fœtal pulp, sufficiently stained with chloride of gold, I have observed that the medullated nerve-fibers upon approaching the periphery of the pulp are destitute of their myelin sheath, and now, being bare axis-cylinders, split into numerous extremely delicate beaded fibrillæ,—the "axis-fibrillæ." They are marked by a dark-violet color, and run in the light rims between the rows of the odontoblasts near the pulp-tissue proper, and are connected with the odontoblasts by means of delicate conical offshoots. In some instances I have observed that these axis-fibrillæ terminated in knob-like extremities. But whether the nerve-fibers directly anastomose with the dentinal fibers I am unable to say. That an indirect connection of the two is established by the intervening reticulum of living matter, I positively assert.

FIG. 152.



SEGMENT OF THE PULP OF A TEMPORARY TOOTH, STAINED WITH CHLORIDE OF GOLD.

M, myxomatous connective tissue; *N*, terminal non-medullated nerve-fibers, in a uniformly granular protoplasmic layer; *O*, rows of medullary corpuscles, termed odontoblasts; *F*, dentinal fibers between the odontoblasts; *D*, dentine. Magnified 1200 diameters.

The results of my researches of the normal pulp are as follows:

I. The dental pulp is a variety of connective tissue termed myxomatous, representing an embryonal form of it. Some authors have called this form of tissue "adenoid," but this term is admitted to be erroneous.

II. The myxomatous tissue of the pulp is intermixed with a delicate fibrous connective tissue in varying amounts.

III. The pulp-tissue is traversed by a closed system of blood-vessels,—viz, arteries, veins, and capillaries. At least one artery is invariably found in the pulp, and it is by no means of exceptional occurrence that the pulp contains several arteries. Lymphatics in small numbers are also present.

IV. The pulp-tissue is richly supplied with nerves, which, in the shape of bundles of medullated nerve-fibers, traverse the myxomatous tissue. Toward the periphery of the pulp they lose their myelin sheaths, become non-medullated, and, in the shape of minute beaded fibrillæ, branch between the odontoblasts.

V. The odontoblasts at the periphery of the pulp are elongated protoplasmic formations with rows of nuclei. They are medullary corpuscles such as we see wherever a new tissue arises from a former one. They build up the basis-substance of the dentine by solidification (transformation into glue, and infiltration with lime-salts). The reticulum of living matter traversing the odontoblasts remains unchanged in the basis-substance of the dentine.

VI. The dentinal fibers originate between the odontoblasts. Being formations of living matter, they are in direct connection with the reticulum of living matter,—first of the odontoblasts and afterward of the basis-substance of the dentine. The connection between the ultimate nerve-fibrillæ and dentinal fibers is very probably an indirect one by means of the intervening reticulum of living matter.

CHAPTER XX.

THE PERICEMENTUM.*

The pericementum (root-membrane, or alveolo-dental periosteum, or periodontium, etc., as it has been termed by former writers) is a formation of fibrous connective tissue, identical with the periosteum which covers all bones. It consists of a layer interposed between the roots of the teeth and their corresponding bony alveoli, and is common to both. It is continuous with the connective tissue—the so-called sub-mucous layer of the gum—and with the periosteum of the maxillæ. Its fibers are connected with the cementum of the root as well as with the wall of the alveolus. A few writers have described the pericementum as a double membrane, one portion of which belongs to the root, the other to the alveolus; we ourselves have not been able to see anything that justifies such a discrimination. In many of the specimens examined, the connective-tissue bundles of the pericementum may be traced from the socket to the cementum of the root of the tooth, or in connection with the reticular structure in the vicinity of the root. Exceptionally we see, close around the root, a thin layer of very dense and fine fibers, the general direction of which is not quite identical with that of the connective tissue which produces the main mass of the pericementum. The relations between the soft and the hard formations of the jaws are very plain in specimens obtained from grown cats, and in all essential points are in accordance with those perceived in specimens taken from the human jaw.

The course pursued by the connective-tissue bundles is slightly wavy and oblique, starting from the cementum and running upward toward the alveolus. The bundles of this tissue are dense, without many decussations. The parallel direction of the bundles begins to change into a diverging one at about the height of the border of the socket, where the bundles become coarser, decussate, and thus produce the elastic connective-tissue cushion, termed the gum.

From the anatomical disposition of the pericementum, conclusions may be drawn as to its physiological action. It is evident that the relatively soft and elastic layer between the two bony formations—the cementum and the alveolus—is designed to lessen the concussion upon the jaw-bones during mastication. The oblique direction of the connective-tissue bundles is the most favorable for the suspension of the tooth within its socket, as the bundles correspond to the funnel shape of the socket, in the center of which is situated the conical root of the tooth. The elasticity of the layer of pericementum admits of a slight degree of motion of the roots; hence we understand the formation of facets on the approximal surfaces of the crowns of the teeth in crowded maxillary arches.

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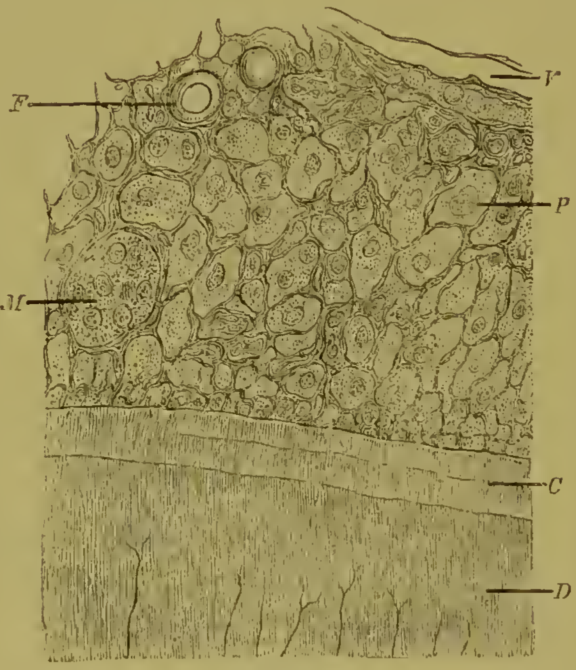
* "Pericementum and Pericementitis." *Dental Cosmos*, 1879–1880.

Fig. 153.



Pericementum of Myxomatous Structure.

D, dentine; *C*, cementum of neck; *P*, pericementum; *M*, multinuclear body; *V*, capillary blood-vessel; *F*, fat-globule with a vacuole. Magnified 500 diameters.

We observe two varieties of pericementum,—one of a reticular structure, termed myxomatous; the other altogether fibrous. The myxomatous variety I have met with, as a rule, in young individuals. It consists of delicate fibers, or bundles of fibers, in a net-like arrangement, and having, in many instances, round or oblong nuclei at the points of intersection. The meshes contain either a hyaline, apparently structureless, sometimes finely-granular basis-substance, or they hold protoplasmic bodies, provided with a varying number of nuclei. The nearer to the cementum, the narrower is the myxomatous reticulum, and the smaller, therefore, are the inclosed protoplasmic bodies. The latter, in the immediate vicinity of the cementum, stand in more or less regular rows, entirely analogous to the protoplasmic bodies around the developing bone-tissue, known, since Gegenbaur, as "osteoblasts." Some of the meshes of the myxomatous tissue are considerably larger and contain multinuclear protoplasmic bodies, termed "myeloplaxes" by Robin, of Paris; "giant-cells" by R. Virchow, of Berlin, and "myeloid cells" by English authors. Other meshes hold fat-globules, which, in specimens preserved and hardened in a solution of chromic acid, very often contain closed spaces,—so-called vacuoles. The myxomatous reticulum is traversed by numerous blood-vessels, mainly capillaries and veins, some of which may be seen entering the medullary spaces of the compact bone of the wall of the alveolus, and in connection with the capillary system of the cancellous portion of the alveolus. I have met with but few nerve-fibers in my specimens.

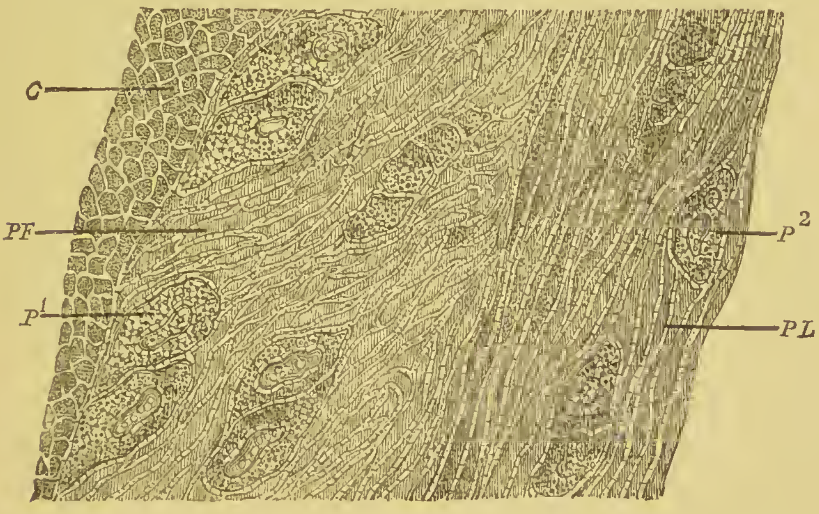
Fig. 153 illustrates a portion of the myxomatous variety of pericementum as shown with a relatively low power. High amplification of the microscope plainly demonstrates the delicate reticular structure of all protoplasmic bodies; the reticulum being visible not only in the contents of the meshes, but also within the fibers of the myxomatous reticulum. The latter feature is best recognizable on specimens deeply stained with chloride of gold. The apparently structureless or indistinctly granular myxomatous basis-substance, held in the meshes of the myxomatous reticulum, proves to be of a reticular structure just as well as the protoplasm itself.

The second variety of pericementum is built up of fibrous connective tissue, which prevails in adults and persons of advanced age. The bundles of the fibrous connective tissue may be uniform in width throughout the whole pericementum; or there exists a zone of tissue of myxomatous or indistinctly fibrous character close around the cementum. The bundles are built up of a number of fibers which hold a varying amount of protoplasmic bodies; as a rule, more numerous the nearer to the cementum. On the latter there may be found rows of osteoblasts or scattered protoplasmic bodies alternating with bundles of a delicate connective tissue, which are directly attached to the cementum. In a few instances we see rows of osteoblasts, the refracting power of which has been considerably augmented. Such corpuscles look shining and structureless, evidently because of a deposition of lime-salts. The fibrous variety of the pericementum also contains fat-globules, sometimes in a surprisingly large quantity.

High magnifying powers of the microscope reveal a structure of the fibrous connective tissue, as follows: The fibers, a certain number of which combine in the formation of a bundle, are delicate spindles, directly connected with one another at their pointed ends. These spindles are separated from each other by narrow layers of a light substance, to the presence of which Tomsa first drew attention, and for which he proposed the term "cement-substance." This substance is doubtless kindred to the gluey basis-substance which mainly builds up the spindles of the connective tissue. The interstices between the spindles are traversed in a vertical direction by extremely minute threads every way analogous to the thorns in the cement-substance surrounding epithelial elements. These threads in many instances are visible in specimens hardened by the chromic-acid solution; they become very plain when thin sections have been immersed in a half per cent. solution of chloride of gold for one or two hours, or until the specimen has assumed a dark-violet color. If the stain be complete, we also recognize that the spindles are not homogeneous, as they look in fresh, unstained specimens, but are rather traversed by a delicate, dark-violet reticulum, the points of intersection of which are slightly thickened, and thus represent granules. (See Fig. 154.)

Between the spindles of the basis-substance protoplasmic bodies are seen the formerly so-called connective-tissue cells. Some of these bodies exhibit shining, compact, oblong nuclei, with a certain amount of surrounding protoplasm, while others are devoid of nuclei, and split into spindle-shaped or polygonal lumps, which in size and shape fully correspond to the elementary formations of the fibrous basis-substance. Where there is a central nucleus, it is invariably bounded by a light rim, which is pierced by radiating thorns. The latter connect the circumference of the nucleus with the granules of the protoplasm next to the nucleus. The protoplasm under all circumstances exhibits the well-known reticular structure. From the periphery of a protoplasmic body, each being surrounded by a light rim, minute threads spring forth, and run into the reticulum within the spindles of the basis-substance. The same relations are seen in protoplasmic bodies next to the cementum,—the so-called osteoblasts. The offshoots of these formations run partly to the spindles of the basis-substance and partly into the light reticulum within the cementum. In some instances, between the cementum and the osteoblasts there is interposed a small layer of fibrous basis-substance in the shape of delicate slender spindles. The walls also of the capillaries, consisting of a single layer of endothelia, are connected with the neighboring spindles of the basis-substance by means of delicate threads, which traverse the light rim around the blood-vessels,—the so-called perivascular space. Lastly, such offshoots run also into the light reticulum of the bone-tissue, where the pericementum is attached to the wall of the alveolus.

Fig. 154.



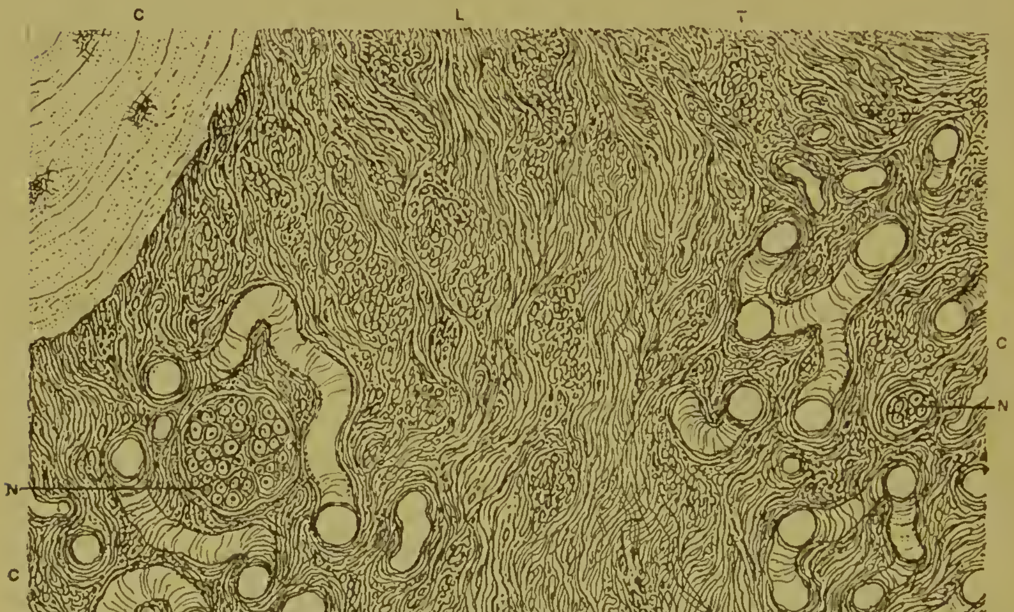
Pericementum of Fibrous Structure.

C, cementum of root; *PL*, pericementum, the fibers of which are built up of spindles, in longitudinal section; *PF*, pericementum, the elementary spindles of which are finer, and cut obliquely; P^1, P^2, protoplasmic bodies, either so-called connective-tissue corpuscles or so-called osteoblasts. Magnified 1200 diameters.

In its juvenile condition the pericementum represents a myxomatous connective tissue, the fibrous portion of which is relatively scanty, while the protoplasmic portion prevails. In this instance two varieties of basis-substance occur,—viz, the fibrous, building up the reticulum, and the myxomatous, filling a certain portion of the meshes. This condition arises, first, from the indifferent or embryonal tissue, not only in the pericementum, but in all formations of connective tissue which, when fully developed, exhibit a fibrous structure. The only way to explain the formation of the myxomatous tissue is that a part of the protoplasm constituting the embryonal elements remains unchanged, a part is transformed into spindles of myxomatous reticulum, and a part into myxomatous basis-substance.

Whereas the myxomatous variety of pericementum is rich in blood-vessels, the fibrous variety is but scantily provided with them. The broadest portion of the pericementum, that around the apex of the root, shows peculiarly tortuous arteries and arterioles, in some places coiled into tuft-like formations. C. Wedl was the first to describe such arterial tufts in the pericementum. Fig. 155 is an illustration of two arterial coils. Tortuous arteries we invariably find in tissues and organs exposed to frequent changes in their bulk, and it seems that the slight mobility of the tooth, owing to the varying amount of pericementum, accounts for the presence of arterial coils.

FIG. 155.



COILS OF ARTERIOLES IN THE PERICEMENTUM. HORIZONTAL SECTION.

C, cementum at the apex; *L*, longitudinal fibers of pericementum; *T*, transverse fibers of pericementum; *C*, *C*, coils of arterioles; *N*, *N*, bundles of medullated nerves in transverse section. Magnified 100 diameters.

CHAPTER XXI.

ERUPTION OF THE TEETH.

For the first eight or ten months after birth, infants require only liquid food, and in a normal condition they have during that period no teeth above the gums. Instead of teeth, upon the anterior portion of the jaws we observe comparatively hard and rough eminences of the mucous membrane, designed to hold the nipple of the mother's breast in the process of sucking. At the time of birth the cusps—cutting-edges—of the crowns of most of the temporary teeth are situated on a level with the alveolar process, covered only by the mucous membrane. The calcification of the teeth commences at their cusps or cutting-edge, and gradually extends to the root. The first teeth usually make their appearance about the sixth or seventh month after birth, although no definite time can be predicated. There are several cases on record of children born with teeth; while on the other hand, the author has seen children who began to cut their teeth no earlier than at the age of twelve or sixteen months. When the crowns of the temporary teeth make their appearance through the gum, the roots are but partially formed, as is illustrated in Fig. 120, taken from an article by C. N. Peirce.*

Fig. 156.

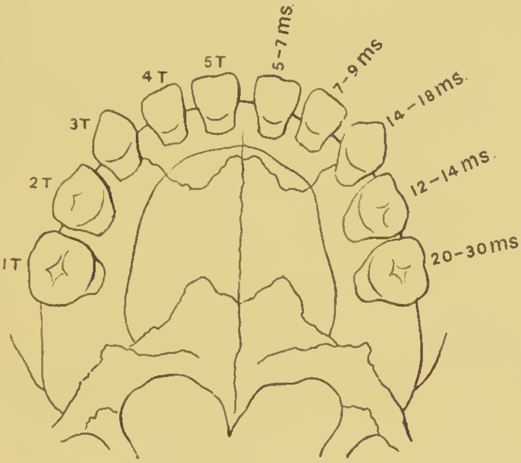


Diagram of Eruption of the Temporary Teeth.

The time considered normal for the eruption of the temporary teeth is as follows. (See Fig. 156.)

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* *Dental Cosmos*, August, 1884.

Fig. 157.

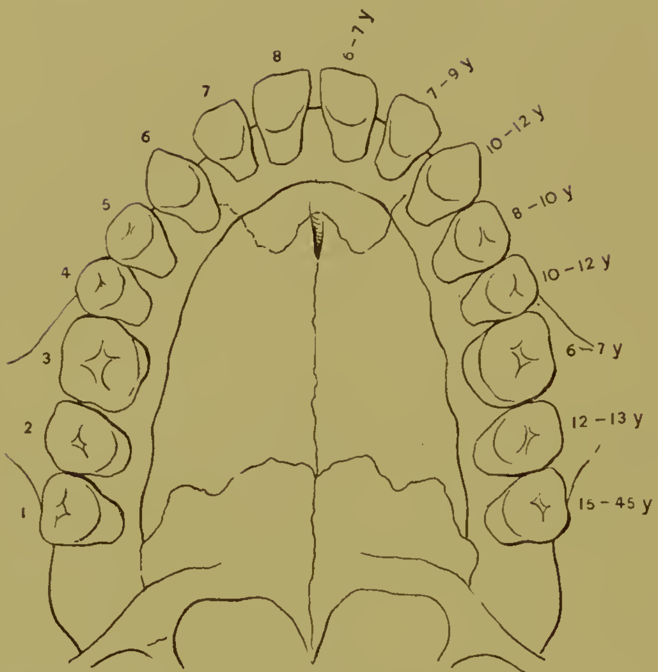


Diagram of Eruption of Permanent Teeth of the Upper Jaw.

Fig. 158

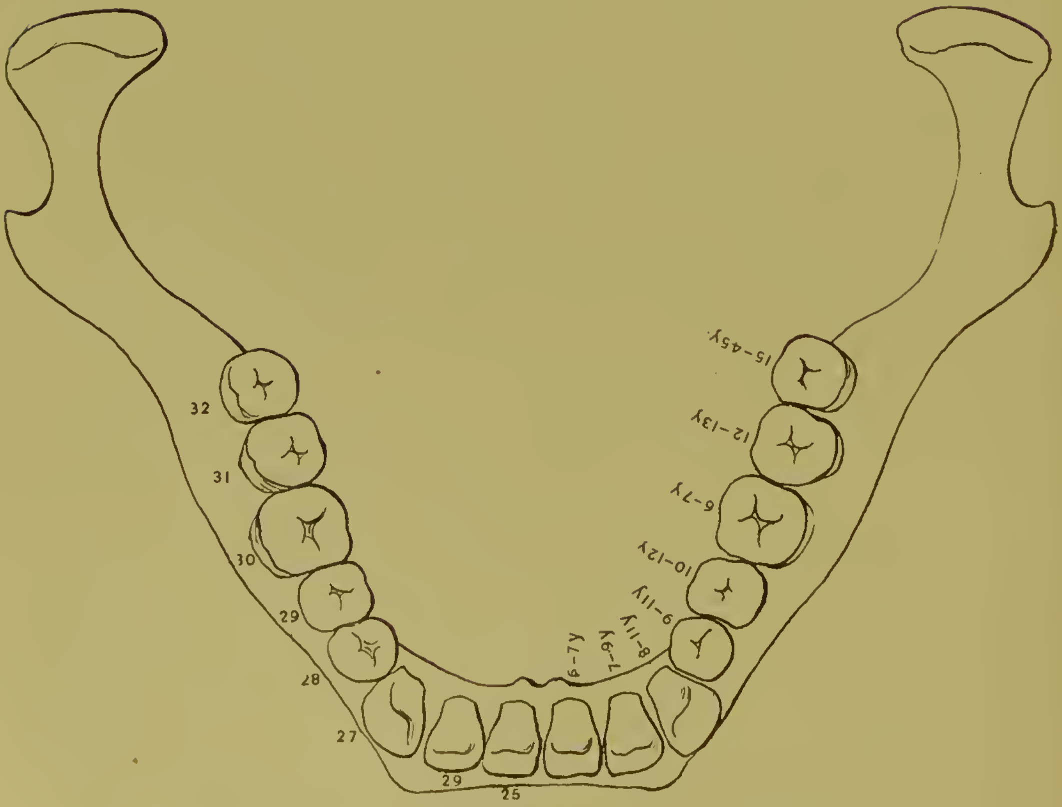
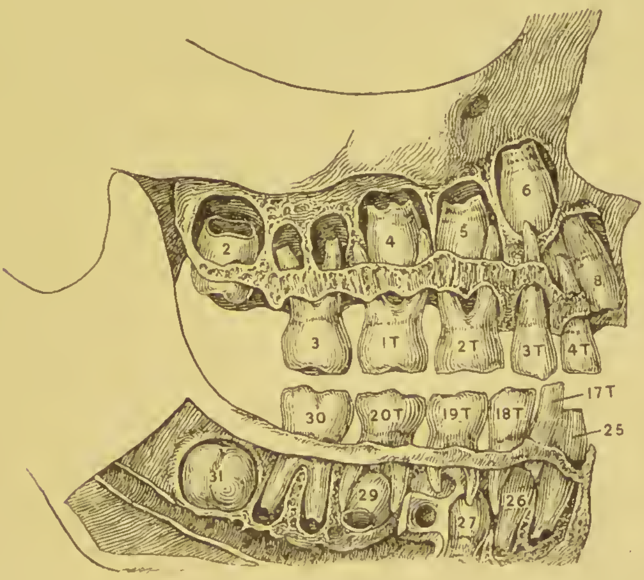


Diagram of Eruption of Permanent Teeth of the Lower Jaw.

The central incisors from the fifth to the seventh month.
The lateral incisors from the seventh to the ninth month.
The first molars from the twelfth to the fourteenth month.
The cuspids from the fourteenth to the eighteenth month.
The second molars from the twentieth to the thirtieth month.

The temporary teeth, under normal conditions, remain in their respective places in the mouth until they are replaced by the permanent teeth, the first of which are usually erupted at about the sixth year. Occasionally we meet with children who shed their teeth earlier,—at the fifth year or even before; while in other instances the permanent teeth do not appear before the eighth or ninth year. We frequently find that a patient has retained one or two temporary teeth up to the thirtieth or fortieth year of his age, these being sometimes quite firm in their sockets.

Fig. 159.



Shedding of the Temporary and Appearance of the Permanent Teeth, between the Fifth and Sixth Years.

The time considered normal for the temporary teeth to fall out and to be replaced by their successors is as follows. (See Figs. 157 and 158.)

The central incisors from the sixth to the seventh year.
The first molars from the sixth to the seventh year.
The lateral incisors from the seventh to the ninth year.
The upper first bicuspids from the eighth to the tenth year.

The lower cuspids from the eighth to the eleventh year.

The lower first bicuspids from the ninth to the eleventh year.

The upper cuspids from the tenth to the twelfth year.

The second upper and lower bicuspids from the tenth to the twelfth year.

The second molars from the twelfth to the thirteenth year.

The third molars from the fifteenth to the forty-fifth year.

On the first appearance of the permanent teeth, their roots, like those of the temporary teeth at that period, are not completed. A consideration of the time of calcification of the roots of the teeth is therefore important, especially as the teeth of young patients often are attacked by caries, and sometimes by pulpitis. (See Fig. 159.) It is evident that when the pulp of a tooth with an incomplete root dies, the saving of that tooth becomes very problematical.

CHAPTER XXII.

ABSORPTION OF TEMPORARY TEETH.

At a certain age the temporary teeth become loose, and sometimes fall out without causing pain or loss of blood.

A temporary tooth shed in this manner usually exhibits only a crown somewhat hollowed out underneath, in the place whence the former root united with it, or a small portion of the root may still be present. Upon macroscopical examination we find the concave bottom of the crown worn away into irregular grooves and pits. Some of these bays may contain small pieces of vascularized soft tissue, the "*carneous body*" of older writers. Originally, the temporary teeth, like those of the permanent set, are possessed of roots which gradually become shortened by absorption, as the growth of the permanent teeth proceeds.

Frank Abbott has thoroughly studied the appearances of the absorption of the deciduous teeth, and has published his results in an essay.* I fully concur with the author in all essential points, and quote from him as follows:

"The assertion of Tomes, that absorption is due to the presence of a freely-vascularized papilla, does not explain the decrease of the dental tissues, for the papilla is nothing but medullary tissue, such as we meet with in any part of the organism, where one tissue is about to change into another. Such a papilla may be the cause of the absorption, as well as its result. Another assertion, that the medullary cells eat out the dental tissues by their active growth, or by their amœboid motions, is insufficient to explain the loss of the lime-salts in the dental tissues, as well as to explain the presence of circular or semi-circular excavations and bays so characteristic of the melting process of the cementum and dentine of deciduous teeth.

"Since we know that pieces of dead bone or ivory may be absorbed, with figures similar to those found on the surface of temporary teeth, the idea possibly becomes admissible that, owing to the presence of an acid, first the lime-salts are dissolved away within certain territories of the dead bone-tissue, in a merely chemical or passive manner, whereupon the soft medullary tissue penetrates the spaces thus established. Quite different, however, will be the conception of this process, if we bear in mind that the temporary teeth, as well as the permanent ones, are made up of living tissues, and an active participation of these tissues must be expected in the process of transformation of the dental into the medullary tissue. As the process of absorption is closely allied to the process of inflammation, and active changes of the dental tissues have, beyond any doubt, been proven to follow inflammation, we may *a priori* expect such changes of the bone-tissue of the temporary teeth in the process of absorption also."

The process of absorption of deciduous teeth is, indeed, closely allied to the inflammatory process, and may be considered as a physiological type of tissue-changes owing to the presence of some irritating agency. The dissolution of lime-salts in bone, as well as that of the hard tissues of the teeth, probably is due to the presence of lactic acid. The dissolution of the lime-salts may invade dead bone-tissue, or invade pieces of ivory implanted in a living tissue. In such dead bone or ivory we likewise observe the disappearance of the lime-salts in the bay-like excavations, which later are filled with a living tissue growing into the excavations from without.

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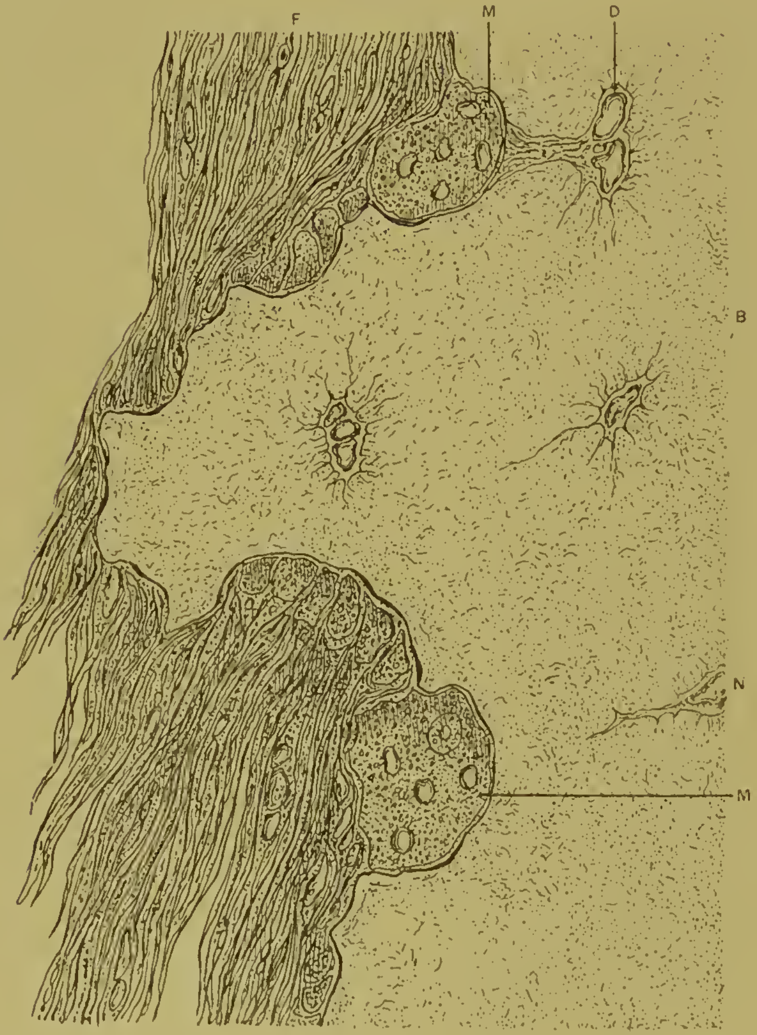
* "Microscopical Studies upon the Absorption of the Roots of Temporary Teeth."

When a temporary tooth begins to be absorbed, its constituent tissues unquestionably are alive, and consequently it is reasonable to assume that the outermost layer of the root, first exposed to the irritation, will react as other living tissues do in the inflammatory process.

FIG. 160.



ABSORPTION OF CEMENTUM OF A TEMPORARY TOOTH.

D, cement-corpuscles in division; *N*, cement-corpuscles unchanged; *B*, basis-substance of cementum; *M*, *M*, multinuclear protoplasmic bodies; *F*, fibrous connective tissue. Magnified 500 diameters.

Whether or not dentine and enamel actively participate in the process of absorption is doubtful, and up to the present day unproven.

Absorption of Cementum.—The first changes due to absorption are semi-circular excavations or bays on the surface of the root of a temporary tooth, filled with embryonal corpuscles or multinuclear protoplasmic bodies, in connection with the myxomatous or fibrous connective tissue of the pericementum. According to Abbott, isolated excavations may be seen, the connection of which with the outer surface, though not observable in the specimen, may be present above or below the plane of the section. He says, "By closely watching excavations of a more recent date, at the periphery of earlier ones which are in communication with the pericementum, we notice that the lime-salts and the basis-substance proper are missing, and are replaced by a uniformly-granular protoplasm, or a varying number of faintly-marked medullary elements, each of which may contain a central nucleus."

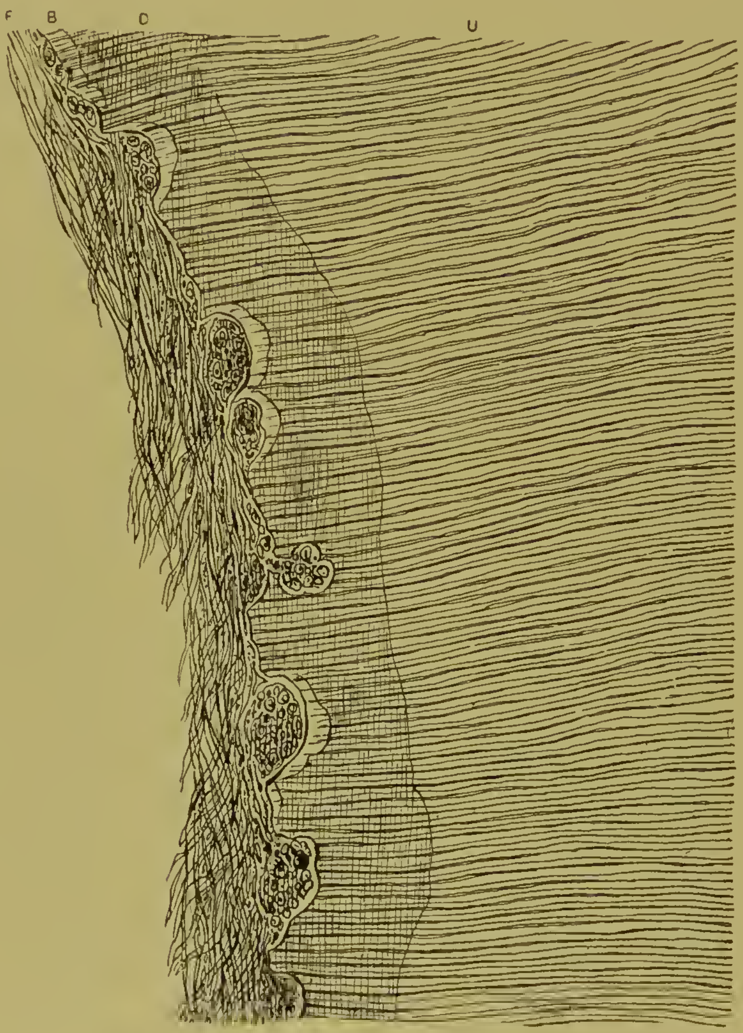
Another proof that the tissue of the cementum reacts upon the irritation is that the cement-corpuscles nearest to the eroded surface frequently are found enlarged, glossy, and split up into smaller pieces. (See Fig. 160.)

The result of such changes is the appearance of embryonal or medullary corpuscles at the border of the excavation, or of multinuclear bodies, formerly the territories of the cementum, now reduced to protoplasm. This indifferent tissue appears connected with fibrous tissue, abundantly supplied with newly-formed blood-vessels. Not infrequently the latter tissue also holds trabeculæ of newly-formed bone, sometimes to such an extent that the widened sockets of the temporary teeth are filled with a considerable amount of cancellous bone-tissue.

Absorption of Dentine.—Dentine, during the process of absorption, if examined with low powers of the microscope at the corroded surface, exhibits a number of bay-like excavations similar to those seen in bone-tissue and the cementum in this process. (See Fig. 161.)

Since we know that dentine, like bone, is formed from medullary tissue clustered together in territories, we are not surprised to find such semi-circular excavations at the exposed surface of dentine during the process of absorption. The bays are filled either with clusters of embryonal corpuscles, or multinuclear protoplasmic bodies, frequently observed in growing as well as in inflamed bone-tissue. These formations are continuous with fibrous connective tissue holding the shortened temporary tooth in position. An important question is, whether or not the dentine of deciduous teeth participates actively in the production of embryonal elements, which afterward develop into fibrous connective tissue. This question is as yet unsettled. If, however, we bear in mind that a deciduous tooth with a living pulp, as a rule, remains sensitive up to the time of detachment from the pericementum, the possibility of such participation cannot be

Fig. 161.



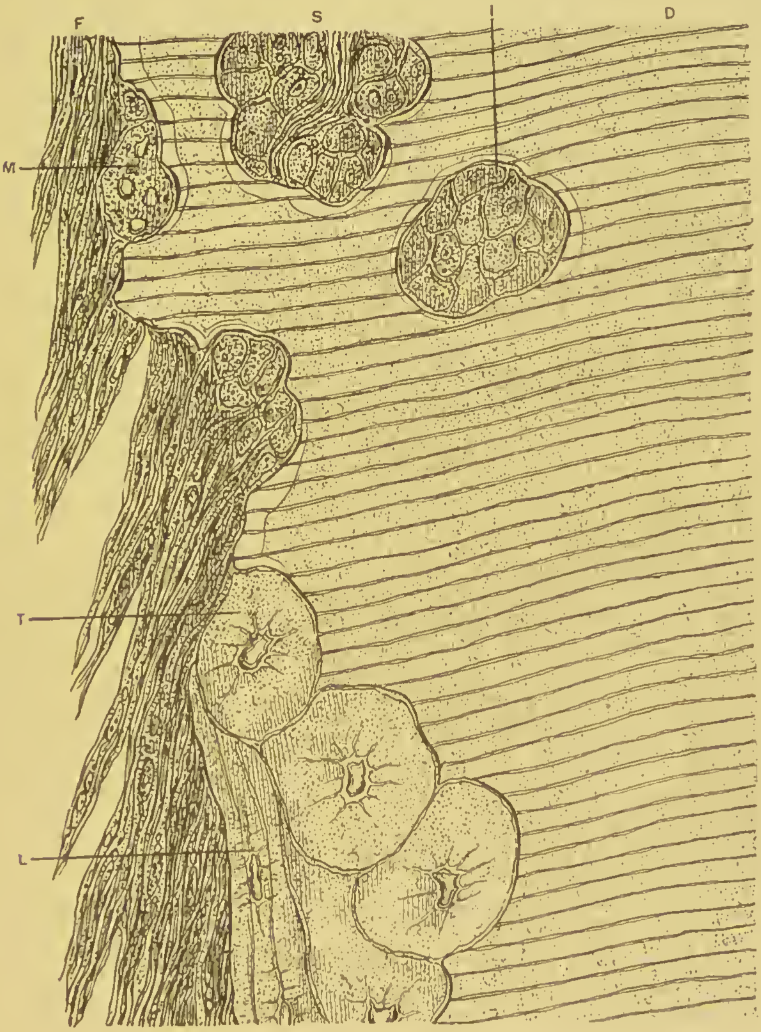
Absorption of Dentine of Temporary Tooth.

U, unchanged dentine; *D*, decalcified dentine; *B*, zone of bay-like excavations; *F*, fibrous connective tissue. Magnified 100 diameters.

denied. Abbott is in favor of assuming it, since he observed a widening of the dentinal canaliculi at the borders of the bays, with an increase of the living matter of the dentinal fibers.

Fields of absorption are frequently met with in the dentine, some distance away from the eroded surface, and apparently

FIG. 162.



ABSORPTION OF DENTINE OF A TEMPORARY TOOTH.

D, dentine without signs of reaction; *I*, isolated medullary spaces; *S*, medullary space filled with indifferent corpuscles and fibrous connective tissue; *M*, multinuclear body filling a bay; *T*, newly-formed territories of bone-tissue; *L*, lamellated bone-tissue; *F*, fibrous connective tissue. Magnified 500 diameters.

isolated. Again, we cannot deny the possibility that such excavations may have been in connection with the surface, and are filled with ingrowing embryonal or myxomatous tissue. (See Fig. 162.)

It is known since J. Tomes, that the bays of the eroded dentine are often found filled with bone-tissue, either in the shape of territories or of lamellated bone. The latter may reach such a degree of development that it produces an almost continuous layer all around the absorbed tooth.

Absorption of Enamel.—This process is but little studied, on account of its exceptional occurrence, which has been mostly observed in the temporary molars.

Bay-like excavations, similar to those observed in the dentine and cementum, occur in absorbed enamel. Chas. Tomes has noticed such bays of the enamel filled with newly-formed bone-tissue, the same as we observe in absorption of dentine. He attributes this rare occurrence to the overlapping of the cement on the edge of the enamel.

CHAPTER XXIII.

PHYSIOLOGY OF THE HARD DENTAL TISSUES.

The latest researches into the minute anatomy of the dental tissues—researches described in previous chapters—necessarily alter the views hitherto held concerning the nutrition of those tissues. Enamel has been considered to be a mere deposit, as it were, of purified lime-salts; a coat of mail destitute of life. The authors in the foregoing chapters have demonstrated the presence of living matter between and within the enamel-prisms, and consequently affirm that enamel is a tissue with properties of life, although in minimum degree. Dentine has long been known to be a tissue extremely sensitive throughout, especially at the interzonal layer bordering the enamel.

Nothing, however, was known as to the seat of life in dentine, until myself and others endeavored to prove not only that the dentinal fibers and their coarse offshoots are formations of living matter, but that the basis-substance, so rich in lime-salts, is traversed by an extremely delicate filigree of living matter as well.

With the facts before us, we may attempt to approach the solution of a hitherto insoluble riddle,—viz, the nutrition of the dentine and of the enamel. No close observer will doubt that the nutrition of the hard tissues of the teeth is—and must be—an active one. This is proven not only by the growth of these tissues, but also by the same tissues' strikingly rapid loss of lime-salts in constitutional diseases, such as neurasthenia, anæmia, etc., and even in pregnancy. How are the lime-salts deposited in the dentine, and how can they be removed to such a degree that dentine, originally hard, becomes in a few months soft and brittle?

Looking at the dentinal canaliculi with the highest obtainable powers of the microscope, we see between the dentinal fiber and the walls of the canaliculus a narrow, light space, evidently filled with liquid, which serves for the carrying of nourishing material to the dentine, and for the carrying of effete material away from it. More than this, even the ultimate fibrillæ of living matter within the basis-substance are surrounded by a delicate light space holding substances that serve the same purposes.

If, besides these points, we observe that the dentinal fibrillæ are of a vacuoled structure, and that the ultimate fibrillæ have a rosary or beaded appearance, we are prepared to acknowledge the possibility that in living dentine the living matter proper is at no time perfectly at rest; that, on the contrary, it is contracting, slowly but continuously, and that through its contractions it not only stirs the surrounding column of liquid, but pumps, as it were, nourishing material into the minutest fields of the dentine, or away from them. The chemical character of the liquid may explain the dissolution of a certain amount of the lime-salts deposited in the blocklets of the basis-substance, which salts, thus being rendered effete, may be carried into the lymphatics of the pulp, and thence into the lymph-system of the body for further elimination. Why, in one instance, nourishing material should be carried from the blood-vessels of the pulp into the dentine, and in another instance carried away from the dentine into the lymphatics, we are as yet unable to understand.

What I have stated concerning the tissue of dentine unquestionably holds good for the tissue of the enamel also. The latter being at the periphery of the crown of the tooth, farthest away from the source of nutrition, and but scantily supplied with living matter, its nutrition must be extremely slow. Still, every dentist must have observed instances of softening of the enamel as the result of constitutional ailments.

Re-calcification, re-hardening of the enamel, though denied by R. Baume, is certainly a fact. The structure of the enamel-fibers between the prisms, as well as of those traversing the latter, points to the identity of the process of nutrition and de-nutrition with that in the dentine. To preserve the life of the dentine and of the enamel, it is not necessary to have the entire pulp of a tooth intact. The experiments of W. Herbst prove, on the contrary, that only a portion of the pulp-tissue left alive in the pulp-canals is capable of keeping alive the dentine and enamel of the crown of a tooth, as I will show in a subsequent chapter.

Another important point seems to be explained satisfactorily by our researches into the structure of the dentine,—*i.e.*, the sensitiveness of this tissue. So striking is this fact that a thoughtful observer such as J. Tomes alluded to the possibility of the dentinal fibrillæ being nerves. Such a view is not tenable, for two reasons:

First, it is, according to our advanced conceptions of histology, impossible to admit of the existence of a connective tissue holding nerves alone in its constitutent soft parts. Second, neither have we, nor has G. Retzius in his recent investigations been able to trace a direct inosculation of the dentinal fibrillæ with the axis-fibrillæ of the nerves, so abundantly distributed throughout the periphery of the pulp-tissue. As soon, however, as we admit that the dentinal fibrillæ are formations of living matter, the same as are the nerves, all difficulties vanish in explaining the transmission of sensation from the periphery of the dentine to the nerves of the pulp-tissue. Living matter is contractile matter, according to Heitzmann. Nerves are made up of living matter, and, owing to their reticulated or beaded structure, are fittest for that transmission of contractions from the periphery to the nervous centers which we call sensation. Contraction of the dentinal fibers transmitted into the reticulum of the protoplasm at the periphery of the pulp, and thence into the ultimate nerve-fibrillæ,—all of which formations are proven to be continuous,—are sufficient to explain the transmission of sensation, or, speaking bluntly, of pain.

As to the sensitiveness of enamel, very little is known. It is denied altogether by R. Baume and others. Nevertheless, the simple experiment of eating a sour apple tends, in my judgment, to prove sensitiveness of the enamel. The sensation which attends what is called "setting the teeth on edge," following in this instance, is noticed not only in permanent teeth whose enamel is ground off, but also in children having perfectly sound enamel upon their temporary teeth. Nobody will explain this sensation on the assumption of a solution of the lime-salts of the enamel, and a penetration of the apple's acid to the surface of the dentine. It is far more probable that the pain is due to the irritation of the living matter of normal enamel, and the transmission of its contractions to that of the dentine, with which it is continuous. That enamel, under morbid conditions, may become extremely sensitive, is a fact known to every dental practitioner.

A third point may be cleared up by these researches,—*i.e.*, the discoloration of devitalized teeth. The discoloration concerns not only the dentine, but also the enamel; indeed, the latter is the first to show the stain. The absence of a nourishing fluid, and the shrinkage of the fibrillæ of living matter in both tissues, may account for their opacity and change of hue.

The minute anatomy of the hard tissues of the teeth, lastly, throws light upon the nature of their senile changes. In temporary teeth the dentinal canaliculi are noticeably wider, and their tenants, the fibers, larger than in permanent teeth. In the enamel-tissue the interstices between the prisms are widest, and their tenants, the enamel-fibrillæ, largest, in developing teeth, at the seventh month of intra-uterine life. In the enamel of permanent teeth the interprismatic spaces are very narrow, and their tenants so delicate that both the spaces and the fibrillæ have escaped the notice of previous observers.

With advancing age, all formations of living matter diminish in bulk, whereas the basis-substance, and the lime-salts held therein, increase in amount. This explains the fact that the teeth of old people have but extremely narrow dentinal canaliculi, and that the total number of these is noticeably lessened by a transformation of previous dentinal canaliculi into basis-substance. This has been before proven to be likewise true in the case of bone- and cartilage-tissue, by Heitzmann and Spina.

The pulp-tissue gradually decreases in amount with advancing age. This is due, as I shall show in a future chapter, to a successive transformation of the pulp into secondary dentine. Nevertheless, not a single instance is known of the complete solidification of a tooth in old age, even though the pulp-tissue be reduced to a minimum, and the pulp-canals barely accessible to the finest broach.

Regarding the physiology of the cementum, little can be said, since there are no anatomical facts as yet observed upon which we can base conclusions. The dentine and the enamel derive their nutrient material from the blood-vessels of the pulp. The cementum has an additional source of nutrition in the blood-vessels of the pericementum. Should the pulp-tissue perish, either in consequence of disease or of the application of arsenious acid, etc., the dentine and the enamel become devitalized. In the case of the cementum, devitalization from such cause is not an inevitable result, since there remains a possibility of its being kept alive by the pericementum. Nothing positive has as yet been ascertained fixing the boundary at which life ends in the hard dental tissues.

That with advancing age the teeth become loose and fall out, may be due to a lack of nutrition in the pericementum, as well as to a shrinkage of the sockets in their transformation into fibrous connective tissue. Not a single instance is known in which, with advancing age, the pericementum ossifies, and the teeth become anchylosed; but, on the contrary, in all instances they loosen and are shed.

CHAPTER XXIV.

GENERAL DIAGNOSIS OF THE DISEASES OF THE TEETH.

The line between normal and morbid processes in the tissues cannot always be distinctly drawn. It is necessary to be thoroughly familiar with the formation of normal tissues, in order to comprehend their pathological conditions. The formation of secondary dentine and bone upon the wall of the pulp-chamber of a tooth can hardly be called pathological, whereas the same formation in the body of the pulp often causes marked disturbances.

The art of differentiation of diseases is called "diagnosis," and the ability to discern pathological conditions occurring in the oral cavity is the aim of every thorough dental practitioner.

It is not an easy matter to establish a correct diagnosis in every case of disease of the oral cavity. In some instances the origin of the trouble is quite obscure, and there are many different diseases that exhibit almost similar subjective symptoms.

The ability to diagnosticate well is only attainable by means of a comprehensive knowledge of the tissues involved, in their normal as well as in their diseased states, and such a knowledge is only attainable by experience in observation. A dental practitioner who carefully studies the condition of his patient will often be able to advise him of some chronic disorder in his (the patient's) system, even before the latter has any knowledge of it himself. The teeth and gums, therefore, may be regarded as indicators of the general health of their possessor.

In order to do this, we must carefully notice the color and condition of the gums, the saliva, and the teeth: the transparency, density, and sensitiveness of the latter, and likewise the consistency of the calculary deposits around them.

The **tartar** being important in the diagnosis of constitutional disturbances, I here will add a brief description of its characteristic features.

There are three varieties of deposits found upon the teeth,—viz, *the white*, *the yellow*, *and the green.*

The white deposit, *or "materia alba,"* as it has first been termed by Leuwenhoek, is of mucoid consistency, principally found upon the labial surfaces of the ten anterior teeth near the gum-margin. It is found upon loose teeth and those not much used. It may accumulate from want of cleanliness, or in constitutional disturbances. According to W. D. Miller,* it consists of epithelium, salivary corpuscles, masses of bacteria of varying sizes and forms, intermixed with particles of food. Dependent upon the constitution and habits of the person, this deposit may be of an acid or alkaline reaction, and, if abundant, in time may cause a chronic inflammation of the gums and the pericementum.

Yellow tartar accumulates around the necks of the teeth more or less in every mouth. It is the result of a deposition of lime-salts into the so-called materia alba. When first formed, it is almost white, but soon becomes yellowish, whereas the portion in contact with the gum mostly is of a darker color, varying from a deep yellow to a dark brown, or even black. The color of this deposit somewhat depends upon the rapidity with which it is formed. Persons afflicted with rheumatism or gout usually have an abundance of yellow tartar, often collected in a comparatively short space of time, of a light color and soft consistency. The healthier the person, the darker is the hue and the harder the consistency of the tartar. Such tartar is found mainly upon the teeth in the neighborhood of the openings of the salivary ducts. Mastication, especially of hard substances, prevents the deposition of salivary calculi upon the teeth; they consequently accumulate more upon that side of the mouth which is least used.

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* *Dental Cosmos*, 1894.

The green deposit frequently is seen upon the teeth of juveniles and those who do not clean their teeth properly, besides in persons who work in metals or have taken metals or their salts in the form of medicines. It is found mostly on the labial surfaces of the upper front teeth, while the lower ones are seldom affected. The color of the deposit in juveniles varies from a light to a dark grayish- or bluish-green. According to Miller (*l. c.*), who was the first to give this matter careful attention, green deposits may be of organic or inorganic origin. The organic stains upon the teeth are believed to be derived from sulphomethæmoglobin present in the coloring-matter of the blood, as well as chromogenic color-producing bacteria. The discoloration of the teeth due to inorganic substances, according to Miller, mainly is produced by copper, iron, mercury, and lead.

Copper stains are characterized by a greenish discoloration of the labial surfaces of the teeth, principally those of the upper jaw. Together with this stain, a red or greenish-brown line is sometimes present upon the gum-margin. It is found upon the teeth of people employed in the working of copper or its alloys. Occasionally it is also met with in trumpeters, where it arises from the contact of the brass mouth-piece with the teeth. (Miller.)

Iron deposits are recognized by their brownish color. (Miller.) They are found upon the teeth of persons working in iron factories, and those who take iron compounds as medicines. Iron stains occur more frequently upon the lower than upon the upper teeth.

The stains of mercury, when arisen from its chlorides, are of a dark-gray or brownish-black color; while the sulphide of mercury may cause a greenish deposit. (Miller.)

Lead, according to Hirt, produces a dark-brown discoloration on the necks of the teeth of persons suffering from lead-poisoning: besides, we usually find the characteristic bluish line upon the gums.

It is believed (Robinson, Harris, Leber and Rottenstein, Fox and Harris, Baume, Brandt, Ottolengui, Schlenker, etc.) that the green-stain so frequently observed upon the teeth of juveniles, and those who do not clean their teeth properly, has an injurious effect upon the enamel; while Miller asserts that the dissolution of the enamel often found under such stains is independent of the latter. True it is that we often see the enamel of the labial surfaces near the gum-margin roughened without being stained.

Dark-gray or blue and cloudy-looking enamel on teeth that are highly sensitive to the touch of an excavator or bur, indicates the tendency to rapid decay. Then the calculary deposits around the necks of such teeth (especially the lower ones) are of a light-yellow or almost white color, and are of very soft, or even slimy, consistency. In many instances the pulps of such teeth are attacked by pulpitis, and die without having been exposed. When the gums are soft, and bleed easily, even at the lightest touch; when they are coated with viscid mucus, and are more or less detached from the necks of the teeth, these, in general, are signs of a weak constitution, or of an impaired one.

We often remark the rapid destruction of teeth where there exists a diseased condition of the system, and with our best efforts we are unable to save them. When the ailment or weakness, however, is of temporary duration, as in the state of pregnancy, the teeth, as a rule, return to the normal character after delivery. If the health of the woman is good, we observe that the saliva soon loses its acidity and viscidity. The enamel and the dentine gradually regain their former transparency and hardness; the teeth become less sensitive at their necks, and the gums, usually independently of treatment, are restored to a healthy state.

It is the rule that the above-described conditions of the mouth are symptomatic in weakly-constituted persons, yet exceptionally we remark those conditions in quite healthy people. Where there is a strong general constitution in the possessor, the teeth are commonly coated with yellow or yellowish-white, hard, and transparent enamel. The dentine, as well as the cervical margins of the necks of the teeth, are not very sensitive: the calculary deposits are of a dark-brown or black color, and of hard consistency. The saliva is usually neutral, or of slightly alkaline reaction, clear and *watery*, not viscid. The gums are of pale red color, hard, do not bleed easily, and are tightly attached to the necks of the teeth. The teeth themselves decay very slowly, and the carious dentine is of a dark-brown or black color.

Sometimes cavities of decay in teeth of this type are left exposed for months, or even years, without any visible extension, so long as the health of the patient remains good. When, however, through chronic diseases of the kidneys, liver, or the nervous system, the health of the patient fails, we soon begin to notice a marked change in the tissues of the teeth and of their surroundings, though the patient, as we intimated before, is perhaps unaware of his ailment.

The first visible changes, in such a case, take place in the gum around the necks of the teeth, especially of the lower incisors. Where three or six months ago we observed hard gums, of a pale rosy color, and tightly encircling the necks of the teeth, we now see on the gum a dark-red or perhaps a bluish band, indicative of the early stages of pyorrhœa alveolaris. The salivary calculus, formerly quite hard, of a brownish color and of slow accumulation, appears now as a yellowish-white, creamy deposit, and more profusely, especially at the necks of the affected teeth. With the advance of the systemic disease progresses the caries of the teeth, the carious matter being now of a light-yellow color, or white, while the teeth become extremely sensitive, not only to the touch of excavating instruments, but even to thermal changes. The saliva is quite viscid, and of a distinct acid reaction.

The teeth under these conditions soon lose their normal color and transparency, become brownish, bluish, or greenish, and the enamel and dentine are extremely soft. The pulps die readily, sometimes without pain, and frequently are found to produce alveolar abscesses, and extensive necrosis, or cystic formations in the jaws. When such signs of a decline in the normal standard of health in the oral cavity are remarked in a patient whom we have known for years, the prognosis is usually alarming. In order to make clear what I have stated, I shall cite two typical cases of my practice.

Mr. W., about forty-five years of age, of an excellent constitution, consulted me in November, 1880, in regard to the restoration of the lingual surfaces and cutting-edges of his remaining five upper front teeth, and the labial surfaces and cutting-edges of the ten lower front teeth. The teeth were of a yellowish-white color, with exceedingly hard enamel and dentine. The left upper second molar had been carious over twelve years, but as some one had advised Mr. W. to have the tooth extracted rather than filled, he had allowed it to remain in that condition. The color of the carious dentine of this tooth was brownish-black, and it was almost as hard as enamel, while the pulp was found to be dead. The fifteen front teeth were restored with gold to their normal length, while the three canals and the cavity of the second upper molar were filled with oxychloride of zinc. Those teeth were quite comfortable till October, 1888, when the lower teeth began to exhibit the symptoms of pyorrhœa alveolaris, and the left upper lateral incisor, during a period of four months, had changed in color to a dark blue. When the pulp-chamber was opened, a great quantity of pus was discharged from the socket, through the tooth, denoting the presence of a chronic alveolar abscess and necrosis. On examination of the other teeth, it was found that most of them were decayed around the necks, while the second upper molar was altogether broken down.

The carious portion of the dentine was now exceedingly soft, and the necks of the teeth were covered by a yellowish-white mucoid deposit, quite acid in reaction. In response to my query as to the gentleman's health, he replied that he had never felt better in his life. I advised his family to inform his physician that I had grave suspicions regarding Mr. W.'s general health. An external examination was made, without an analysis of the urine, and no serious danger was reported.

In time the teeth of the patient were destroyed; some of the lower incisors falling out in consequence of pyorrhœa alveolaris, while others lost their crowns through caries. In October, 1893, he died of chronic parenchymatous nephritis (Bright's disease of the kidneys), though there had been no previous warning of his illness beyond that which I have described.

Miss P., about eighteen years of age, with a good constitution, was the possessor of an almost perfect set of teeth, except that upon the grinding-surfaces of the four first permanent molars the enamel was not perfectly calcified. The grinding-surfaces of these four teeth were restored with gold, in October, 1887. The other teeth were of a bluish-white color, quite hard, and but little sensitive to excavation. The mouth, as well as the face of the patient, at that time, presented a typically healthy appearence. I saw her in June, 1888, May, 1890, June, 1891, when I filled only ordinary cavities in the grinding-surfaces of the teeth, which up to that time were in a normal condition. I saw the patient again in March, 1892, when I noticed a great change in her dentures, gums, and saliva, as well as in her general countenance. The face had changed to a pale grayish hue; the eyes had lost their former brightness; the teeth were quite soft, very sensitive, and of a dark-blue tint. The gums were light pink, except around the lower incisor teeth, where I noticed a slight inflammation. The saliva, although watery, had a distinct acid reaction. Upon examination, I found five large carious cavities in the teeth, the dentine of which, in the process of excavating, proved to be exceedingly soft and sensitive. Upon the query as to the state of her general health, she replied that she was as well as ever. I advised the patient to see her physician in regard to her general condition, but she did not think it necessary, the more so as she intended to leave for Europe in about ten days. Shortly before her departure she did not feel quite well, when her physician was consulted, who announced that she was suffering from a severe disease of the nervous system, *Basedow's* or *Graves's disease*, to-day termed *exophthalmic goitre.*

In the diagnosis of the diseases of the mouth, we must carefully consider:

First. The individual characteristics of the patient, the normal standard of his or her health, and ascertain, if possible, whether the system is deranged by temporary or constitutional disturbances, such as menstruation, pregnancy, anæmia, chronic diseases of the nervous system, of the liver, or of the kidneys, the effects of external or hereditary influence, etc.

Second. Pathological phenomena in distant parts, resulting from reflex action of irritated nerves.

Third. The minute anatomy of the immediately involved parts, and the laws governing their progressive as well as retrogressive changes.

Fourth. The observations of our senses, in physical examination, in the use of instruments, or by other methods.

Fifth. The subjective symptoms which are the local or general phenomena of the disease, as noticed by the patient himself.

Sixth. The differential diagnosis, which is the consideration of the features that distinguish one disease from another disease, when there are like symptoms in both.

The prognosis consists of the conclusions arrived at in a summing up of all the above-intimated phenomena, collectively considered.

In physical examination of the diseases of the oral cavity, we employ, besides our sense of sight, the senses of touch, hearing, and smell; sometimes, also, light, percussion, heat, and cold.

At sight we are, in many cases, enabled to determine the general state of a patient's health. Before making a physical examination of the oral cavity, we ought to observe the shape, color, and expression of the patient's face and eyes, as well as his general countenance. To be able to see the differences of the normal tissues of the oral cavity from those that are diseased, we must become familiar with their normal appearance. We should study the normal color and aspect of the gums and tongue of persons of different constitutions. We shall then be able to discover conditions of inflammation in the oral cavity, even where these are slightly indicated, recognizing them by the mere difference in color which the inflamed mucous membrane exhibits in contrast to the normal one.

The sense of touch is of great importance, and is one that ought to be cultivated to perfection by every dental student. It is employed either directly at the point of the index finger, or indirectly by means of a probe or any other instrument. In most cases of pericementitis and periostitis we are enabled to ascertain by means of the index finger to what degree the inflammatory process has advanced. In a physical examination we should always compare the diseased part of the oral cavity with the corresponding usually normal portion of the opposite side. In this investigation the finger will easily find whether or not there exists a swelling on the gums, which portion is hard, unyielding, and of normal temperature, or soft, hot, and fluctuating. More important, however, than the examination by the point of the finger, is that which exercises the sense of touch through the medium of an instrument. This can be developed to accuracy only by ample practice. We may train our sense of touch to such perfection that we become able to differentiate between all tissues with which the probe comes in contact, determining whether the substance touched be soft tissue, or enamel, or dentine, compact or cancellous bone; distinguishing also whether the latter tissue be living or necrotic, and discriminating from one another steel, gold, amalgam, etc., when they are hidden from view.

The most frequent examination of the dental practitioner is the search of the teeth for carious cavities. In many instances these are easily found. There are patients who experience pain as soon as a small cavity exists, which may hardly have penetrated the interzonal layer. In other instances we encounter patients who have many cavities, and the teeth in many places broken down, and who, notwithstanding, have never complained of toothache. In the latter cases, examination should be made carefully on all surfaces of the teeth; whereas, in an instance of the former description, the patient himself may designate the locality of the caries.

In examining the teeth for caries, we employ a mouth-mirror and a delicate steel exploring instrument. The teeth frequently decay on their approximal surfaces; and where they stand so close together that we cannot penetrate the interstices even with the finest broach, it becomes difficult to determine whether or not the tooth contains a carious cavity. In the majority of teeth decayed on the approximal surface, the cavity may be detected in the incisors, the cuspids, and the bicuspids by a bluish line on the respective labial or buccal surfaces, when concentrated daylight or electric light is thrown under the lingual surfaces. When a carious cavity is small, however, we may fail to detect it even by transillumination of the teeth. In such a case we are obliged to separate the teeth slightly, either at once by a screw separator, or gradually by cotton or wood wedges or other suitable means.

Examination of the teeth should always be systematic. We ought to begin, regularly, with the last molar, either of the upper or the lower jaw. In examining a single tooth, much may be overlooked,—perhaps even the seat of the trouble, since it frequently happens, where two or three teeth are decayed on the same side of the mouth, that the patient attributes the pain to a wrong tooth. The grinding-surfaces of the teeth should be first carefully explored, then the approximal, next the buccal, respectively labial and lingual surfaces, and at last the necks slightly beyond the gums. For the latter purpose, it is advisable to repeatedly moisten the exploring instrument with a solution of corrosive sublimate, 1 to 1000, although the instrument may have been thoroughly sterilized before. The exploring instrument should be handled very delicately between the thumb and the first two fingers, somewhat like a pen in writing. The instrument should be moved along the surfaces of the teeth mainly by the muscles of the fingers, whereas the joint at the wrist ought to be employed but exceptionally. When a cavity is deep, and we expect to find the pulp of the tooth exposed, it is desirable to exert a slight pressure in the region of the pulp, a small piece of cotton making a satisfactory interposition. No pointed instrument should be introduced into a deep carious cavity in the vicinity of the pulp.

If the patient feels no pain upon slight pressure with cotton, this means that the pulp is either not exposed or is partially or wholly devitalized. In every instance of deep-seated caries it is advisable to remove the decayed dentine by as large an excavator or round bur as the cavity will admit. Small instruments, by perforating the protecting thin layer of dentine, are likely to enter a healthy pulp, and besides causing severe pain to the patient, may produce acute pulpitis, which is likely to cause the death of the pulp.

Percussion.—When the hammer of a piano is thrown against one of the expanded wires, it causes the wire to vibrate and produce a sound. Similarly, if we slightly hammer with an instrument upon a normal tooth, we cause the tooth and its surrounding tissue to vibrate and produce a sound, which, however, in duration and resonance cannot be compared with that produced by the string of the piano.

In the practice of medicine, the diagnosis of some of the diseases of internal organs is based upon sounds, produced by hammering upon the external surface of the body under which the diseased organ is situated. The latter, according to its consistency and condition, upon percussion, renders back a resonance characteristic of the organ when normal. In its pathological conditions the sounds it returns in percussion are materially altered from those of the normal state. In dental practice, slight percussion upon the teeth by means of the point of a finger, or with an instrument, aids us to arrive at a diagnosis of some of the forms of pulpitis and pericementitis. Especially in cases of pericementitis in its earliest stages, often when the patient as yet has felt no pain nor discomfort in the affected tooth, we shall be able to notice, upon percussion of the tooth, a sound somewhat duller than the normal; while its neighbor, or its fellow on the opposite side of the mouth, upon percussion, produces a normal sound. In comparing the resonance of a tooth with that of its neighbor, or that of a tooth on the opposite side of the mouth, care must be exercised to strike similar teeth in the same direction. For satisfactory results much depends also upon the position of the tongue, the lips, and the lower jaw. If the mouth is wide open, the resonance of the teeth will be higher in pitch than when the mouth is nearly closed. In percussion of the teeth, we notice five different sounds,—viz, the *high*, the *low*, the *clear*, and the *dull*, as well as a *somewhat tympanitic sound.* When the mouth is wide open, we obtain the high sound; when nearly closed, the low one. When we hammer slightly upon the crown of a normal tooth, we obtain a clear sound. If, on the contrary, percussion is made upon a tooth which in the process of pericementitis has become loosened in its socket, we shall perceive a distinct dull sound. A somewhat tympanitic sound is produced by percussion upon the second upper bicuspid, still more pronounced in the first molar of the upper jaw.

In physical examination, we also have to consider the general condition of all the teeth in the mouth. The teeth of some patients, upon percussion, always give out a dull sound. These teeth usually are somewhat loose in their sockets, although their pericementum appears normal. Such patients may be young or in the prime of life, whereas we meet with persons quite old whose teeth, firm in their sockets, produce a clear sound on percussion. We have to take into consideration, also, the number of roots which the tooth possesses. As a general rule, we find that a tooth with two roots gives out, on percussion, a sound a trifle clearer than does a tooth of but one root, while the upper molars give the clearest sound of all. Therefore, in making, by means of percussion, a diagnosis as to a bicuspid or molar tooth, it is advisable to compare its sound with that of the corresponding tooth on the opposite side of the mouth. The six anterior teeth of the upper jaw, if normal, yield, on percussion, sounds nearly equal in clearness. There is, however, sometimes a slight difference in the sounds rendered by the upper incisors from those of the cuspids, a difference probably due to the length of the roots. In a series of percussions from the first upper bicuspid to the second upper molar, we notice a gradual increase in the pitch of the sound, due to the existence of the antrum, which, being filled with air and communicating with the nasal cavities, causes a more or less tympanitic resonance.

Although, as in cases of hyperostosis of the roots, the sounds produced by percussion on the corresponding teeth of opposite sides of the mouth are not always identical, yet, with experience, we will soon be able to differentiate between the sounds of a tooth with a normal, and of a tooth with an inflamed, pericementum. In cases of slight circumscribed pericementitis, we are often enabled to localize the inflamed portion in the pericementum, unless this be situated on the mesial or the distal surface of the root, and unless the crowns of the teeth stand in close contact with those of their neighbors. Percussion upon the crown of a tooth in the direction of the inflamed spot will produce a somewhat dull sound. Therefore, if pericementitis is seated in the lingual portion of the root of the tooth, slight percussion upon the labial, respectively buccal surface of the crown, in the direction of the inflammation, will produce a duller sound than that evoked when, by the same instrument, the tooth is tapped on the lingual surface. If, on the contrary, pericementitis is seated in the apex of the root, percussion in that direction upon the crown of the tooth will evoke the characteristic dull sound. In this manner we are often enabled to ascertain which of the roots of a molar or first bicuspid tooth is inflamed. The degree of the dullness of the sound depends upon the degree of the inflammatory condition of the pericementum. Therefore, the more diffused the inflammation around the root of the tooth, the duller will be the sound and the greater the sensitiveness on percussion. Thus the character of the sound produced by percussion of the teeth principally depends upon the continuity, the elasticity, and the surroundings of the vibrating tissue. In more advanced stages of pericementitis, on percussion of the affected tooth, we notice, besides a distinct dullness in sound, sensitiveness or pain, increasing in severity with the advance of the inflammatory process of the pericementum.

By our *sense of smell* we detect septic conditions of the oral cavity, especially in diseases of the antrum and the pulp. In order to arrive at a proper diagnosis, it is necessary to be acquainted with the peculiar odors characteristic of an inflamed condition of the antrum, as well as of gangrene of the pulp. There is, also, in the breath of some patients, a peculiar sweetish odor, which somewhat resembles that of chloroform, and is characteristic of a febrile or otherwise diseased state of the system. All these peculiarities should be carefully noticed, as sometimes they may aid us in making a diagnosis.

In diagnosticating pathological conditions of the pulps of the teeth, we also employ the agencies of *heat and cold*, by means of water, air, or the spray of the chloride of methyl. Extreme cold, directed suddenly to the tissues, produces local anesthesia, as is observed in the application of the chloride-of-methyl spray. Extreme heat has the same effect as extreme cold, causing irritation and death when its operation is persistent. Thermal changes wrought suddenly on the tissues, especially those of the teeth, induce pain by causing rapid contraction or expansion of the living matter. In thermal change, however, not suddenly produced, but wrought by mild degrees, heat has the opposite effect on the tissues to that of cold. In general, heat favors activity in the circulation, while cold depresses it. The continued application of heat, therefore, induces an engorgement of the capillaries, at the same time diminishing the quantity of blood in the larger vessels, as well as in internal organs. The continuous application of moderate cold to the tissues induces a contraction of the smaller arteries, and thereby diminishes the quantity of blood. The blood-vessels are under the control of the vaso-motor nerves. Anything, therefore, which stimulates or depresses the nerves, affects the blood-supply in the region of the affected vaso-motor nerve. In the diagnosis of chronic pulpitis, the application of heat and cold is sometimes the only trustworthy means of finding the seat of ailment. In many instances, as I shall show in a later chapter, the patient localizes in one part the pain which really belongs elsewhere. A sudden application, through a syringe, of cold air or ice-water, or of hot air or hot water, to the unaffected teeth and to the affected tooth, as a rule, speedily defines the locality of the disease: the response of intensified pain following the injection into the actually diseased quarter. Care, however, should be taken that but one or two teeth be brought under the direct action of the heat or cold, a precaution which the practitioner carries out by covering the other teeth tightly with bibulous paper or a napkin, and removing, with a saliva-ejector, the hot or cold water that has been used. In cases of a doubtful diagnosis as to the vitality or deadness of a tooth, the application of the chloride-of-methyl spray is the best means of determining the fact. Applied to a living tooth, it causes pain: to a devitalized tooth the application is painless.

Light, either plain or augmented, or by appliances of art, is another agent which we frequently employ in diagnosticating diseases of the antrum, also in ascertaining whether the pulp of a tooth is dead or alive, and in the search for carious cavities.

In 1881, Louis Elsberg, in an address before the Odontological Society of New York, explained the manner in which at that time he was accustomed to illuminate the mouth and larynx by means of Trouve's apparatus. This exposition of his procedure did much to further the improvement of the method, and to bring to perfection the illuminating apparatus now in use. The process commonly followed has been called "transillumination" by W. Freudenthal, who gives a good description of it in a paper read before the New York Academy of Medicine, in 1891. The instrument most effectively employed is a small electric lamp placed under the hard palate, in the patient's mouth, which should be closed as nearly as possible. The lamp will then illuminate the whole middle region of the patient's face, and even the eyes. When both antra are in a normal condition. the illumination is uniform on both sides of the face. If, on the contrary, there is in one of the antra an abnormal growth, or merely a thickening of the lining membrane, the light-rays are obstructed, and according to the extent of the obstructing tissue will the affected part be less illuminated, or altogether dark. The same process may be effectively pursued in the examination of devitalized or carious teeth. To this end the lamp is held as in the former inspection, the patient's jaws being nearly closed, but the lips kept open. In such illumination devitalized teeth appear opaque, while the teeth with living pulps are quite transparent. In some instances the teeth stand so close together in the dental arch that we are unable, even with the finest broach, to search their joined surfaces for carious cavities. In this case transillumination is especially employed with advantage upon the ten or twelve anterior teeth. Cavities that exist in the juxtaposed surfaces of these teeth obstruct the light-rays and show corresponding dark spots.

CHAPTER XXV.

IRRITATION AND NEW FORMATIONS OF DENTAL TISSUE.

In the chapter on the physiology of the teeth I have indicated the manner in which sensation is carried from the surface of the enamel and of the dentine to the pulp; viz, that this is very probably accomplished by the alternate contractions and expansions of the living matter, and that intense contractions induced by highly irritating agencies result in the sensation of pain. We may admit as a fact the existence of contractions in the living matter in such slight degree as not only to be painless, but even devoid of unpleasant sensations.

Such slight contractions, if continuous, are what clinicians term "irritation." Continuous, though slight, contractions of the living matter, conveyed from the periphery to the center of a tooth, may suffice directly to excite contractions of the living matter of the pulp-tissue, and, indirectly, through reflex action, to influence the vaso-motor nerves of a limited region of the blood-vessels of the pulp-tissue.

In either case, we may infer an increased afflux of nourishing material to the irritated part, in which a morbid process takes place, which, naturally, becomes more evident when it reaches the stage of inflammation. The first change in the affected tissue is its reduction to an embryonal or protoplasmic state. The pulp-tissue is made up of a myxomatous tissue holding but little basis-substance,—a characteristic embryonal condition. The presence of small globular lumps of nearly homogeneous living matter, scattered through the basis-substance, and closely resembling lymph-corpuscles, has induced previous observers to term the pulp-tissue an "adenoid tissue," since the lymph-ganglia, throughout the animal body in general, are constructed on the type of pulp-tissue. The lymph-ganglia were, some forty years ago, considered as glands; and they, and the lymph-follicles as well, were called, accordingly, "lymph-glands." This error was committed mainly by German histologists, headed by E. Brücke. To-day we know that the lymph-ganglia are strictly connective-tissue formations, lacking epithelia, the essential secreting constituent of a gland. Hence the terms "lymph-gland" and "adenoid tissue," which convey the idea of a gland-like structure, have been justly abandoned; and, to-day, rejecting the word "adenoid" with its misleading significance, we speak of a "lymph-tissue," which we know to be myxomatous.

Should the lymph-tissue of the pulp be reduced to its embryonal condition as above indicated, the protoplasm present before transformation into myxomatous basis-substance reappears, and may break up either into odontoblasts or into osteoblasts. In the former case, the result of irritation of the pulp-tissue will be *dentine;* in the latter, *bone.*

Odontoblasts are known to be a fore-stage in the production of dentine. If these appear in consequence of irritation, they are never so regular as those of primary, well-developed dentine. Before eburnification the odontoblasts must break up into rows or clusters of indifferent or medullary corpuscles, all interconnected by means of delicate threads of living matter. From these threads arise, as a result of the coalescence of the interconnecting threads, coarser fibrillæ of living matter, the future dentinal fibers.

The original odontoblasts and their derivations, the embryonal corpuscles, being irregular in shape and unevenly distributed and grouped, will, in turn, produce a dentine irregular in structure, scantily provided with dentinal fibers, and often stratified. Such dentine we term *secondary dentine.*

If osteoblasts have been the outcome of the structural change of the pulp-tissue, these osteoblasts, again, will break up into embryonal corpuscles, but, after accomplished calcification of the basis-substance, they will produce bone-tissue. The lime-salts necessary for the production of secondary dentine or osseous tissue are, doubtless, supplied by the capillary blood-vessels, from the serum of the blood circulating therein. It is possible that the capillaries traversing different organs of the animal body hold chemically different contents. The eclectic power by means of which the contents of the capillaries are drawn into the permeated tissues, rests, very probably, in the endothelial walls. Thus the endothelia of the capillaries of the pulp are fitted mainly for the emission of a serum rich in lime solutions, though many capillaries in the irritated part are known to perish, becoming obliterated, solidified, and broken up into embryonal tissue.

The so-called pulp-stones are nothing but secondary dentine or secondary bone, either sessile, *i.e.*, attached broadly to the wall of the dentine, or pediculated, *i.e.*, attached to the dentinal wall by a comparatively narrow foot; or, lastly, isolated in the pulp-tissue, lacking attachment altogether. C. Wedl has announced the theory that pulp-stones are the result of an involution or reduplication of the odontoblast layer of the pulp, directed from the periphery into the center. This view is marred by the fact that the pulp-tissue, if irritated, is capable of producing odontoblasts as well as osteoblasts, in any part of it. To me it seems that merely a slight and steady irritation of a certain portion of the pulp is sufficient for the production of pulp-stones, either of a dentinal or of a bony type, or, as may occur, a mixture of both.

I have stated before that the formation of secondary dentine or secondary bone from the pulp-tissue is the result of a slight, though incessant, irritation of this tissue, frequently unperceived by the person affected. It does not, however, invariably escape the attention of the patient. There are individuals who have a dull uncomfortable sensation in the jaw, whenever the formation of secondary dentine is in progress, though not able to locate this sensation in a single tooth. Others complain of pain in the dentine, which becomes agonizing whenever the teeth are exposed to changes of temperature. Still others are not troubled in the region of the dentures at all, but suffer from neuralgia in various branches of the trigeminus, in branches of the vagus, or even of the cervical plexus.

The irritations here spoken of may be caused by the wearing off of the crowns through advanced age, by caries, by a recession of the gums at the necks of the teeth, by erosion and mechanical abrasion irrespective of age, by inflammatory processes in the pericementum, etc. In some cases, however, no such cause can be discovered, while, nevertheless, secondary dentine or pulp-stones may be found to have developed in the pulp-tissue, even in the case of adolescents from sixteen to twenty years of age. In such cases we account for this fact on the theory that frequent exposure to different extremes of temperature, as in eating hot dishes and ices, drinking hot and ice-cold liquids, may cause the trouble.

Irritation may affect not only the pulp-tissue, but the dentine directly. This is apparent when we notice the consequences of applying caustic or metallic filling-materials. In such cases the irritation, in the portions of dentine that surround the fillings, leads to an increased afflux of serum, saturated with lime-salts, and, consequently, to the obliteration of a number of dentinal canaliculi. The canaliculi and their tenants, the fibers, are then transformed into basis-substance, as I shall show in a further chapter.

An increase of bulk, termed "hyperostosis of the cementum," is of not very uncommon occurrence in this tissue. Doubtless slight but incessant irritation is here, again, the cause of the disturbance. As to the source of the irritation, we are as yet in the dark. Wm. H. Atkinson has alleged that hyperostosis of the cementum occurs only in such a tooth as lacks an opponent. This assertion, however, has been disproved by observation. It is possible that a congenital surplus of pericementum in the patient is productive of the enlargement of the cementum. In this case the movement of the tooth in mastication would slightly exceed the normal degree. The constant irritation of the pericementum under such conditions might cause an increase in the amount of the cementum. The clinical symptoms of hyperostosis are just as obscure as those of the growth of secondary dentine. In some cases the patient is wholly unconscious of the ailment; in others he feels uneasiness, faint discomfort, or even dull pain; again, in others, it may cause reflex irritation in remote parts,—neuralgia, etc.

In this chapter I have endeavored to outline a process summarized in the title "Irritation Causing a New Formation of Dental Tissue." No strict boundary-line can be drawn between this process and that which results in the formation of tumors. According to A. Lücke, irritation and inflammation sooner or later come to a standstill, and cease to be instrumental in producing new tissue; whereas tumors grow indefinitely, never coming to rest during life.

In the absence of a better definition, I shall adopt that of Lücke, and discuss in a separate chapter the congenital or acquired tumors of the teeth.

CHAPTER XXVI.

SECONDARY DENTINE.

In the preceding chapter I have stated that in the event of irritation on the surface of the tooth, the pulp-tissue reacts and produces secondary dentine.

Secondary dentine occurs in two forms: first, secondary dentine in contact with primary dentine and lining the pulp-cavity; and second, dentine in the middle of the pulp-tissue. Whereas the etiology of secondary dentine of the former variety is plain, always being the result of an irritation on the surface of the tooth, the origin of the so-called pulp-stones is not understood. The latter formations are often met with, and often induce pulpitis.

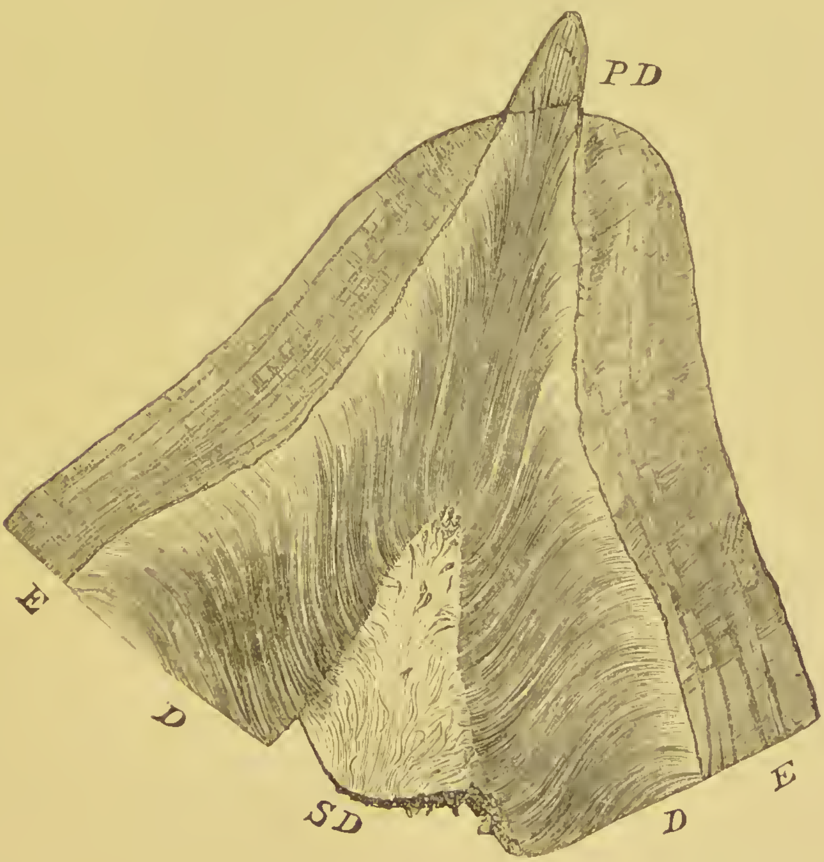
From the upper jaw of a lady forty years of age, I extracted the cuspids, one of which I split to obtain the pulp; the other I ground thin immediately after its extraction, for the purpose of studying enamel. Only one longitudinal section could be prepared. The results were as follows:

The crown was built up of dentine terminating in the ordinary peak, and surrounded by a well-developed cap of enamel, the outermost point of which was lost, evidently in the grinding. (Fig. 163, *PD.*) A marked brown discoloration in the usual fan-like arrangement is noticeable in the enamel, mainly in the immediate neighborhood of the dentine, but without any decay.

The dentine, beginning at the neck and extending down into the root, is divided into two layers, one internal, occupying four-fifths of the root, and one external, of the thickness of the cementum of normal teeth. These two layers of dentine are sharply marked by the difference in the carmin stain, the inner portion being very pale, the outer deeply colored. The boundary between these two layers is everywhere well defined by a scalloped line, the concavities of which look outward. In some places several such scalloped marks run perfectly parallel, close to one another. The boundary line, however, is traversed by the dentinal canaliculi and their tenants without change of direction. The outermost portion of the dentine of the root is surrounded by cementum, not thicker than is seen on the necks of teeth of normal development. In this layer faint parallel striations are recognizable, therefore an indistinct lamellation. The cementum is slightly thicker on one side of the apex of the root, exhibiting there a scanty number of cement-corpuscles, which on all other portions are wanting.

The minute structure of the cementum is identical with that of the neck of a normal tooth,—built up of delicate wavy spindles with narrow interstices. These spindles are missing only on that side of the root where, as mentioned, cement-corpuscles are present and the basis-substance exhibits a relatively coarse granulation.

FIG. 163.

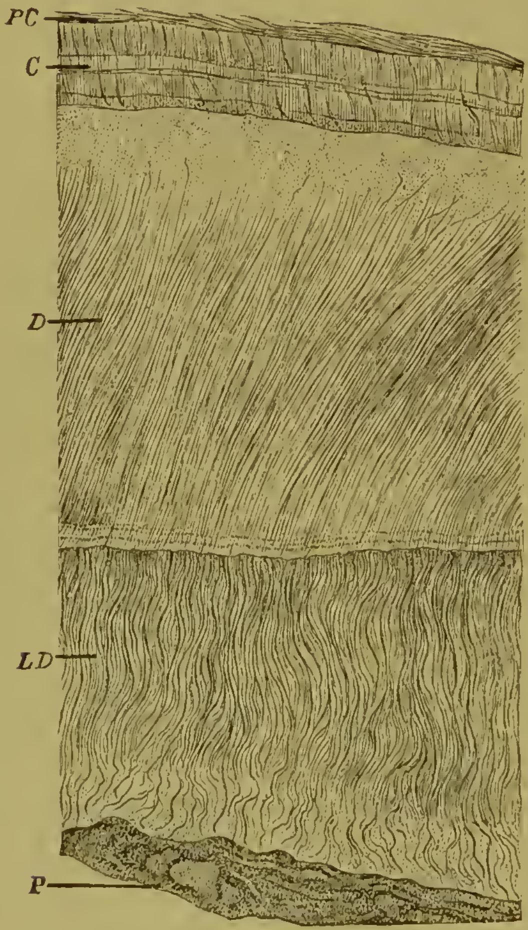


SECTION OF THE CROWN OF AN ANOMALOUS UPPER CUSPID TOOTH.

D, *D*, dentine; *PD*, point of dentine; *E*, *E*, enamel; *SD*, secondary dentine. Magnified 50 diameters.

The boundary between dentine and cementum is sharply defined. The former bears the characteristics of dentine in the vicinity of the neck, as the canaliculi stop short of its surface and are replaced by a coarsely-granular basis-substance. Fig. 164, taken from the lower portion of the root, illustrates the relations just described. Nearest to the pulp-chamber there is a zone of scanty and irregular dentinal canaliculi, the formation which we are accustomed to call "secondary dentine." Next to this is a broader layer of dentine, in which the dentinal canaliculi run in bundles and in a slightly irregular wavy course. Then we see a broad portion of fully-developed dentine (*D*), the canaliculi of which do not reach the cementum, but, beneath

Fig. 164.

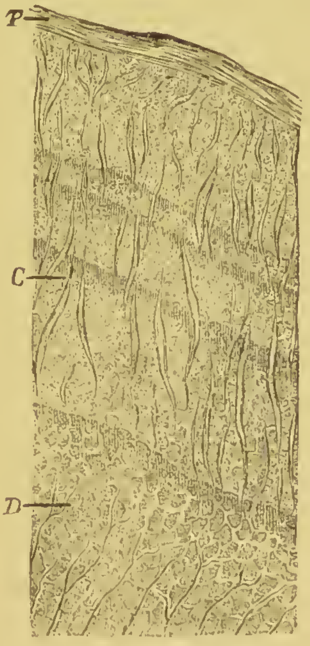


Root of an Anomalous Cuspid Tooth.

D, primary dentine; *LD*, secondary dentine, composed of two zones; *P*, pulp; *C*, cementum; *PC*, pericementum. Magnified 300 diameters.

the latter, are replaced by a coarsely-granular net-work. The scalloped boundary between *LD* and *D* is plainly marked. On the outer surface appears the relatively narrow layer of cementum (*C*) with its lamellated structure, and, attached to this, remnants of the pericementum (*PC*) are visible. Higher magnifying powers of the microscope give an insight into the minute structure of the dentine and cementum (see Fig. 165), taken from the place just described. In the layer of dentine the terminations of the dentinal fibers are seen bifurcated and leading toward the light reticulum, in which we assume the presence of living matter. The lamellated cementum is provided with a number of curved spindles, evidently of protoplasmic nature, which in their general direction correspond to the course of the dentinal fibers, while the basis-substance between the spindles appears finely granular. On that portion of the cementum of the root which is provided with cement-corpuscles a distinct boundary between dentine and cementum is wanting. The pericementum everywhere is attached to the cementum by rows of spindle-shaped bodies in the same manner in which we see it on the necks of normal teeth.

FIG. 165.



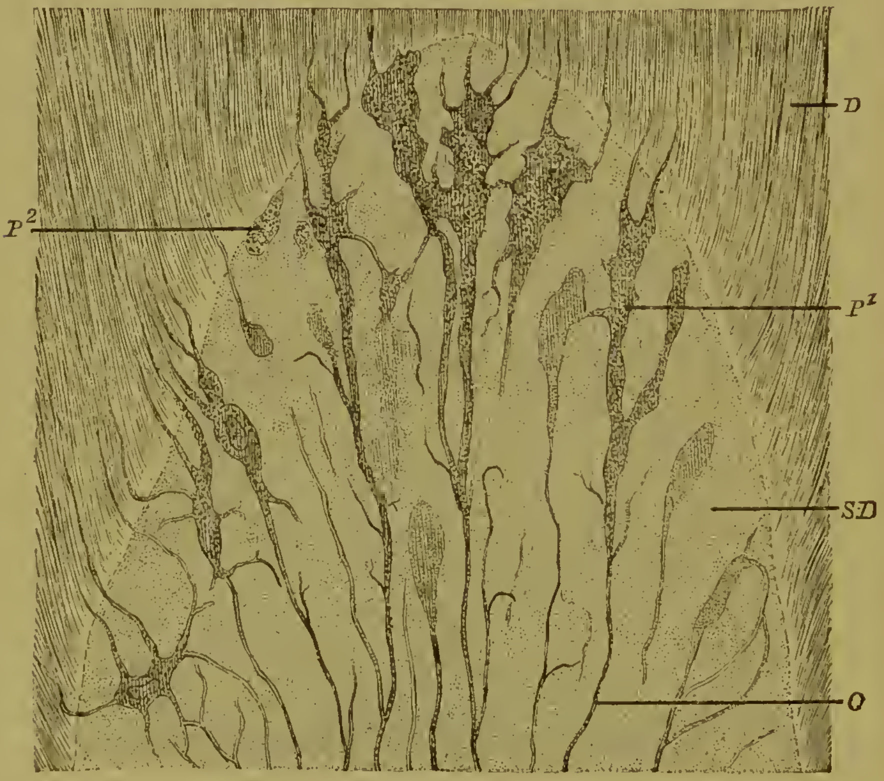
ROOT OF AN ANOMALOUS CUSPID TOOTH.

D, dentine; *C*, cementum; *P*, pericementum. Magnified 1000 diameters.

In this tooth, therefore, the cement-layer is replaced by a regularly-developed layer of dentine, the former being very thin, and, with the exception of a limited portion, devoid of cement-corpuscles. Evidently the tooth originally had a very large pulp-chamber, which, with advancing age, was reduced by the formation of dentine, first regularly and afterwards irregularly provided with dentinal canaliculi. The central portion of the dentine is occupied by "secondary dentine."

In the crown, a conical portion, the blunt lower edge of which binds the pulp-cavity (see Fig. 163, *SD*), exhibits a structure which doubtless has all the essential properties of dentine, though in a considerably more irregular arrangement than ordinary dentine. The regular dentine terminates almost abruptly all around the cone of the irregular dentine. On the apex of the latter are visible large, irregularly-shaped branching spaces, which invariably contain partly-nucleated protoplasmic formations. (See Fig. 166.) The spaces and their respective tenants, the protoplasmic bodies, are mainly pear-shaped, with their bases directed toward the regular dentine, and their elongations passing into the irregular dentine. From the broad bases arise numerous conical offshoots, by means of which a direct communication is established with the dentinal fibers of the regular

Fig. 166.



Cusp of an Anomalous Cuspid Tooth.

D, dentine; *SD*, secondary dentine; P^1, pear-shaped protoplasmic bodies on the boundary between primary and secondary dentine, sending large offshoots, *O*, downward; P^2, protoplasmic body without offshoots. Magnified 500 diameters.

dentine, while other offshoots inosculate with analogous formations on the apex, thus producing a coarse net-work. From the pointed lower ends of the pear-shaped spaces originate wavy canaliculi, which freely anastomose with one another, and traverse the whole mass of the central portion of the crown in a prevailing radiate arrangement. Their number is more scanty than in the regular dentine, so much so that relatively large territories of the basis-substance are altogether devoid of canaliculi. The latter, like the canaliculi of normal dentine, hold delicate beaded fibers of living matter, with the difference that, on the average, the fibers of normal dentine are finer than those of the secondary formation. Some of these fibers are provided with lateral conical offshoots directed toward the basis-substance, which itself shows a delicate reticular structure essentially of the same character as I have seen in regular dentine.

The middle portion of the pulp-cavity is bounded by a narrow zone of dentine, which is possessed of canaliculi in a smaller number than the main mass of dentine. This zone, besides, is characterized by a deep carmin stain, while the regular dentine remained almost unstained. The stained portion is inserted upon the regular dentine by means of numerous shallow excavations, and its surface is irregularly jagged toward the pulp-cavity. In the apex of the root, the irregular formation of dentine again is much thicker than in the middle portion, and provided with numerous roundish spaces, all of which contain protoplasm, and communicate with the irregular, wavy canaliculi of the boundary layer of the pulp-cavity.

From the facts recorded in dental literature, it is evident that there are several causes universally agreed upon as to formations of secondary dentine. These causes are mainly: first, advanced age; second, caries of the primary dentine; and third, injuries on the external surface of the tooth.

Carl Heitzmann, in 1872,* first drew attention to the fact that in old dogs and cats a number of Haversian canals in the compact bone become obliterated. This investigator observed that the capillary blood-vessel, which represents the last remnant of the medullary tissue within the Haversian canals, is finally transformed into a solid protoplasmic mass, which immediately assumes the character of the bony basis-substance. The bone-corpuscles, which under these circumstances are visible in the center of a Haversian system, are, as a rule, larger than those scattered within the lamellæ of an earlier formation.

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* "Uber Rück- und Neubildung von Blutgefassen in Knorpel und Knochen," *Wiener Medicinische Jahrbücher.*

If we consider the pulp-cavity as a medullary space containing blood-vessels, nerves, and medullary elements, around which are arranged the layers of dentine, enamel, and cementum, we find a coincidence of the formation of bone on the one hand, and of secondary dentine on the other, in advancing age. In both instances the medullary elements are transformed into basis-substance; the nerves, probably, after having been reduced to medullary elements, also assisting in the formation of secondary dentine; and, lastly, the blood-vessels are solidified. On an average, the older the person the smaller is the pulp-cavity, until at last hardly any trace of the pulp-tissue is left, and the tooth is an almost completely solid mass.

Opposed to carious destruction of the crown I have repeatedly met with formations of secondary dentine, as described by Salter and Wedl. This occurred, however, only in those forms of caries which have been described by Frank Abbott as chronic. I have specimens which illustrate that such secondary dentine formations, when the carious process has led to the exposure of the pulp and produced pulpitis, are again partially destroyed by the inflammatory process.

As to the irritation from without, first stated by Salter to be the cause of the formation of secondary dentine, I would add chronic pericementitis, which, when limited to one root or to a portion of the root, leads to the formation of secondary dentine in the pulp-canal of the affected root. There are cases, however, in which neither age nor an external injury accounts for the formation of secondary dentine; and one instance is that of the tooth above described. Here, perhaps, the absence of the fully-developed layer of cementum was the reason for such an extensive premature formation of secondary dentine.

The coarser anatomical relations of secondary dentine in general are accurately described by C. Wedl, with whom I fully agree. In analyzing the manifold formations of this kind, I would divide them as follows:

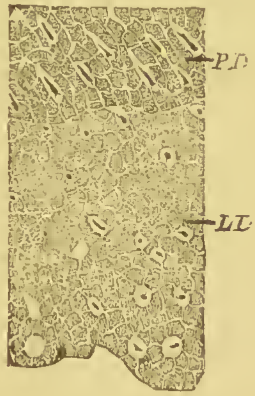
First. Secondary dentine resembling primary dentine.

Second. Secondary dentine with a laminated structure.

Third. Secondary dentine in form analogous to Haversian systems. This latter variety has been termed "osteo-dentine."

Secondary dentine, with the essential structure of primary dentine, is evidently of the most frequent occurrence. It never has the regular arrangement of the dentinal canaliculi as seen in primary dentine, but is marked by a lighter color, owing to the large amount of basis-substance and the relatively small number of canaliculi, which at the same time deviate more or less from the direction of the primary canaliculi. In cross-sections of such secondary dentine,—especially in specimens stained with chloride of gold,—we recognize in each canaliculus a central fiber (Fig. 167), from which delicate conical offshoots emanate toward the periphery of the canaliculus. The canaliculi, which as a rule are the wider the nearer to the pulp-cavity, are pierced on their periphery by light interruptions, leading into a delicate light reticulum throughout the whole basis-substance. In the reticulum, the presence of living matter is not directly demonstrable, but it must be assumed mainly from the phenomena of inflammation,—viz, caries and pulpitis. The secondary dentine sometimes remains in an embryonal condition, exhibiting roundish fields of basis-substance, such as are visible in the dentine of a nine-months' fœtus. The medullary elements being transformed into basis-substance, represent irregular globular bodies, between which the living matter produces the formations known as Tomes's dentinal fibers.

FIG. 167.



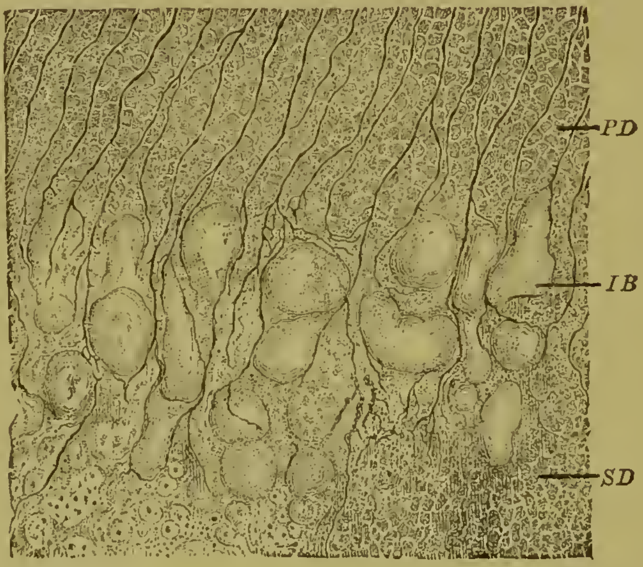
DENTINE OF AN AGED PERSON. CROSS-SECTION.

PD, primary dentine; *LD*, secondary dentine. Magnified 1000 diameters.

This much is certain, that the dentinal fibers of secondary dentine are also beaded, and send lateral offshoots toward the basis-substance, thus indicating the presence of living matter in the latter. (Fig. 168.)

Formations known as "interglobular spaces" are not infrequently met with in normal dentine. They are also quite common in secondary dentine, especially on the boundary between primary and secondary dentine. The tooth first described (Figs. 163 and 166) furnishes beautiful samples of such formations. Most of these are protoplasmic in nature; nay, some exhibit distinct nuclei. The offshoots are evidently fibers of living matter. Some of these, toward the primary dentine, are in direct communication with its fibers; others run in different directions toward neighboring kindred formations, with which they inosculate; others again, after repeated bifurcation, lose themselves in the basis-substance. Exceptionally there occur also protoplasmic bodies without any coarser offshoots. (Fig. 166.)

Fig. 168.



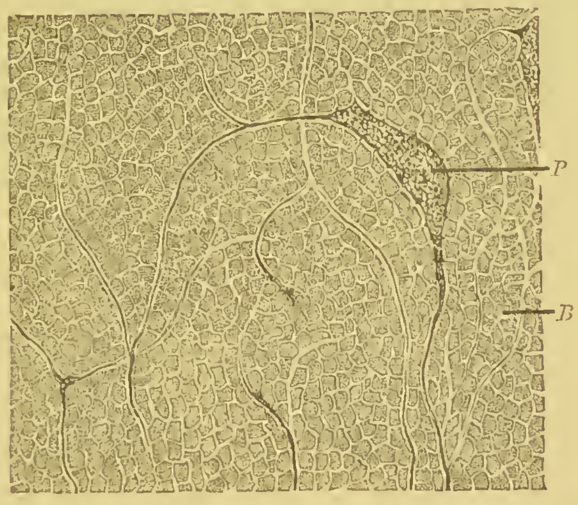
Secondary Dentine, with Globular Formations of the Basis-Substance.

PD, primary dentine; *SD*, secondary dentine, with irregularly-scattered canaliculi; *IB*, globular bodies of secondary dentine, between which the dentinal canaliculi run, all in connection with those of the primary dentine. Magnified 500 diameters.

Higher amplification of these formations plainly demonstrates their minute structures. (Fig. 169.) We see protoplasmic bodies imbedded in lacunæ of the basis-substance, essentially identical with the so-called "interglobular spaces," the tenants of which never could have been made out in sections obtained from dry teeth. The protoplasmic bodies send in different directions into the basis-substance, larger beaded fibers, which are partly in communication with fibers arising from neighboring bodies. Some of the canaliculi I found empty, from which the fibers (evidently in the process of grinding) have been torn out. The protoplasmic bodies on their periphery send conical thorns through the light spaces between the protoplasm and the wall of the lacuna or interglobular space. The pointed ends of these thorns are directed toward the light reticulum, which pierces the basis-substance everywhere.

The second variety of secondary dentine consists of the formation of a lamellated basis-substance, which is traversed by irregular dentinal canaliculi. I have observed in my specimens that the lamellated structure begins close to the termination of the primary dentine in an almost continuous course. The lamellæ themselves never are very regular, and produce broader and narrower layers, which, as a rule, are not strictly parallel to one another. In the interstices between the lamellæ, here and there, I have met with flat layers of protoplasm. The canaliculi piercing the lamellated dentine are generally very narrow, and run either perpendicular or oblique to the lamellæ, with manifold ramifications. They invariably contain delicate beaded fibers of living matter, which send lateral conical offshoots toward the basis-substance, in a much more irregular distribution than we see in primary dentine.

FIG. 169.



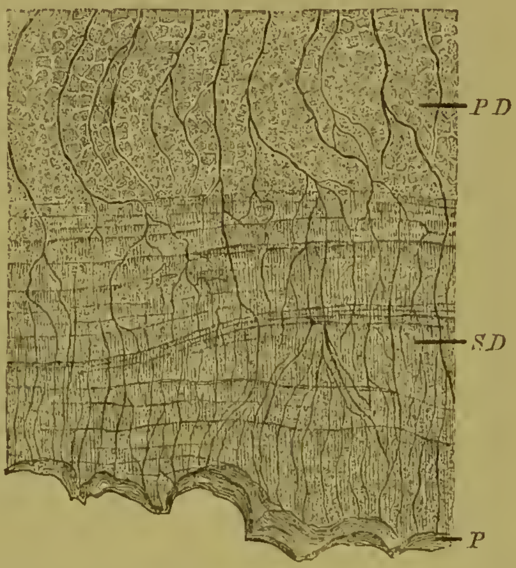
SECONDARY DENTINE FROM CUSPID.

P, protoplasmic bodies with the reticular structure and offshoots; *B*, basis-substance with the light, net-like structure. Magnified 1000 diameters.

On the boundary between primary and secondary dentine we very often succeed in tracing a direct continuity of the canaliculi of the former with those of the latter.

The figure (Fig. 170) which illustrates the lamellated variety of secondary dentine exhibits a peculiar feature of dentinal canaliculi in the primary dentine, near its connection with the lamellated formation,—viz, bifurcations of the canaliculi of the primary dentine, which otherwise do not occur except on their terminations near the enamel and the cementum. The secondary dentine shows bay-like excavations bordering the pulp-cavity, evidently due to an inflammatory process of the pulp-tissue, which has led to the dissolution of the lime-salts. In the specimen from which I have taken the drawing the layer of the lamellated dentine is very broad toward the crown and apex of the root; while the middle portion of the pulp-cavity, though considerably narrowed, has a relatively small amount of secondary dentine on its limits.

FIG. 170.

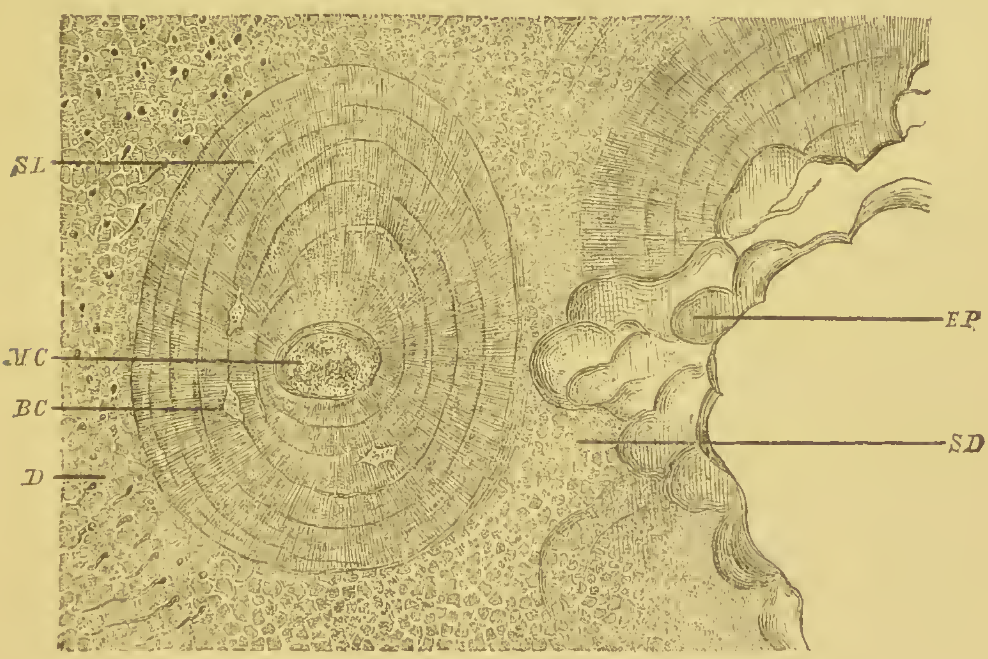


LAMELLATED VARIETY OF SECONDARY DENTINE.

PD, primary dentine; *SD*, secondary dentine; *P*, margin toward pulp-cavity, with bay-like excavations, due to pulpitis. The lamellæ of the secondary dentine are irregular and pierced by dentinal fibers, some of which are in direct connection with those of the primary dentine. Magnified 500 diameters.

The third, and evidently rarest, form of secondary dentine is that known by the term "osteo-dentine." Formations of this kind are either pedunculated,—*i.e.*, connected with the primary dentine by a stem,—or they partly fill the pulp-cavity in the shape of a uniform layer. There is a striking resemblance between osteo-dentine and Haversian systems of bone-tissue. The systems greatly vary in size and shape, and are separated from one another by a tissue kindred to primary dentine, but devoid of dentinal canaliculi. Each system has in its center a medullary canal, containing a certain amount of protoplasmic bodies known as medullary elements; nay, in some of the systems I have met with a central capillary blood-vessel, which has evidently been in direct union with capillaries of the pulp-tissue. Around the medullary canal a system of lamellæ is arranged, sometimes pretty regularly; and the lamellæ are traversed by delicate radiating canaliculi, closely resembling those of bone-tissue. Only exceptionally have I seen within the lamellæ protoplasmic formations analogous to bone-corpuscles. The jagged outlines of the lacunæ, in which the protoplasmic bodies lodge, are identical with those found in bone; and higher magnifying powers of the microscope, in fact, reveal an open communication of the lacunæ with the adjacent canaliculi.

Fig. 171.

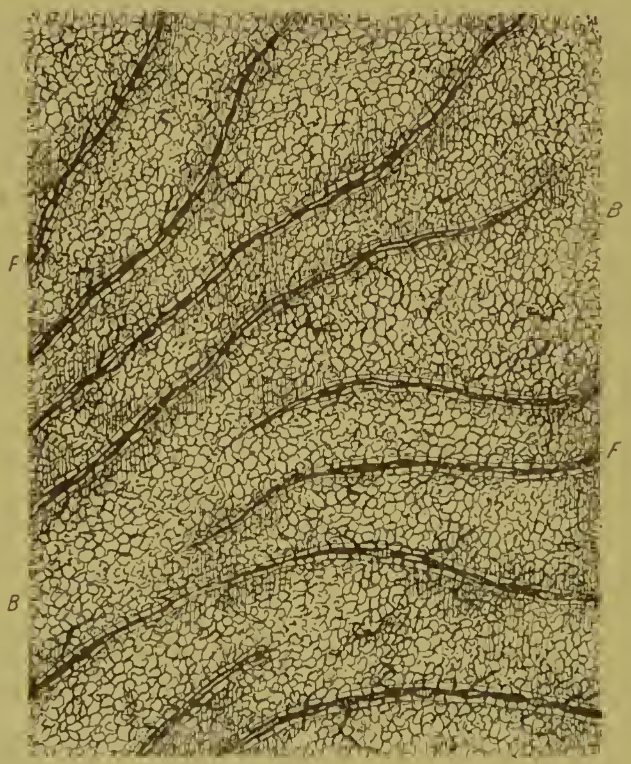


Osteo-dentine, the Third Variety of Secondary Dentine.

D, primary dentine; *SD*, secondary dentine; *SL*, system of lamellæ, resembling those of Haversian systems of bone; *MC*, medullary canal filled with protoplasm; *BC*, small protoplasmic elements, identical with bone-corpuscles; *EP*, erosions of osteo-dentine, due to pulpitis. Magnified 600 diameters.

In the specimen from which I have selected a spot for illustration (Fig. 171), the lamellated systems were developed in a most marked manner; and the blood-vessels in the center of these systems were so regular that they suggested the query whether or not we had here to deal with vaso-dentine, so common in the teeth of fish. These formations occurred in the apex of the root,—some of them in the midst of regular dentine,—while the lowest systems, without any distinct boundary, were connected with the cementum, which latter here and there also exhibited medullary canals.

Fig. 172.



Secondary Dentine of Permanent Molar, Stained with Chloride of Gold, Decalcified with Acetic Acid.

F, *F*, dentinal fibers; *B*, *B*, basis-substance. Magnified 1200 diameters.

A contribution to the minute anatomy of secondary dentine is published by John I. Hart.* His results were obtained in a treatment of protracted staining with a solution of chloride of gold:

"In several of my specimens of permanent teeth, I have met with secondary dentine toward the pulp-chamber. I have seen its two main varieties: the one characterized by the presence of irregular and wavy dentinal canaliculi, distributed in the basis-substance in the form of bundles or sheaves, and the other marked by the presence of bone-corpuscles, the so-called osteo-dentine. I must confine my remarks to the former variety, as the latter was seen accidentally, in dead teeth only. (See Fig. 172.)

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* "Minute Structure of Dentine." *Dental Cosmos*, 1891.

"The dentinal fibers are rather large, and supplied with numerous vacuoles in their substance. Numerous coarser lateral offshoots arise from these fibers, apparently more numerous than in primary dentine. Besides, there were seen coarse conical offshoots springing from the periphery of the dentinal fibers and running into a reticulum, which, in some places at least, was coarser than that of the primary dentine. This reticulum also appeared more irregular in the secondary than in the primary dentine."

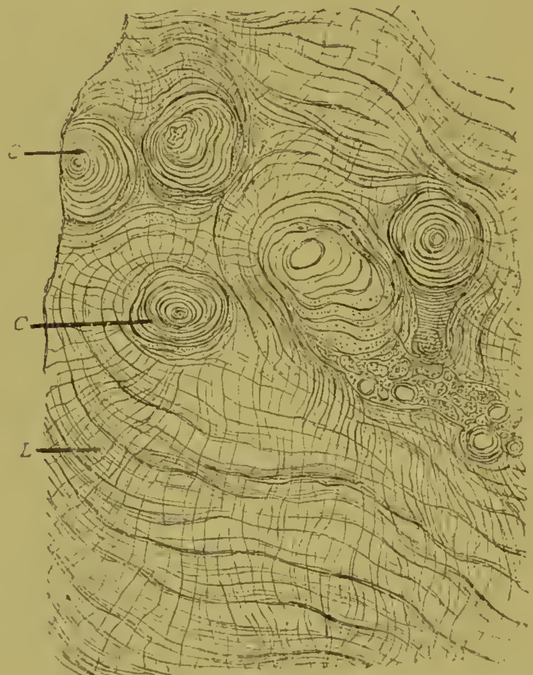
II. Secondary Dentine in the Middle of the Pulp-Tissue.—What previous observers have termed "pulp-stones" or "denticles" I propose to designate as "dentinification," "eburnification," and "ossification" of the pulp-tissue.

It was necessary to invent such terms for the designation of a process which, although known for many years, has never been fully understood. I refer to the new formation of dentine in the middle of the pulp-tissue, independent of the dentine composing the walls of the pulp-chamber. It is the formation of the so-called "pulp-stones" which by some observers are announced as the result of a process of calcification, but by John Tomes, Ulrich, Hohl, Bruck, Baume, and Witzel have been described as a variety of secondary dentine. So-called pulp-stones, as is well known, may be found either connected with the dentine proper by means of a peduncule, or loosely imbedded in the connective tissue of the pulp. Most of these formations are composed of dentinal tissue in the form termed secondary dentine. Of rarer occurrence are those constructed exclusively of a lamellated bone-tissue. Somewhat rarer still are combinations of both dentine and bone-tissue. The rarest are new formations of dentine strictly identical with primary dentine.

1. So-called "pulp-stones" of the character of secondary dentine. The most marked characteristic of these specimens is the presence of dentinal canaliculi irregularly scattered throughout

the calcified basis-substance. Sometimes the canaliculi assume a tolerably well-marked radiation; in other instances, even large masses of calcified basis-substance are destitute of canaliculi. These, in scanty bundles, are found toward the periphery of the pulp-stone. All the three varieties of secondary dentine are found in these formations. Portions of the basis-substance, especially toward the periphery, may exhibit delicate concentric laminations. In the midst of an apparently homogeneous basis-substance, small laminated territories may occur, containing a central corpuscle with branching offshoots, somewhat resembling a bone-corpuscle. In sections of one pulp-stone, I have found numerous concentrically-laminated territories, more or less distinct, and either one or two protoplasmic formations in their centers. The tissue between the territories was partly granular and partly composed of secondary dentine, with irregular canaliculi. Here and there medullary spaces were seen traversing the tissue, from which evidently the new formation of the territories had started. This variety is the regular osteo-dentine.

Fig. 173.



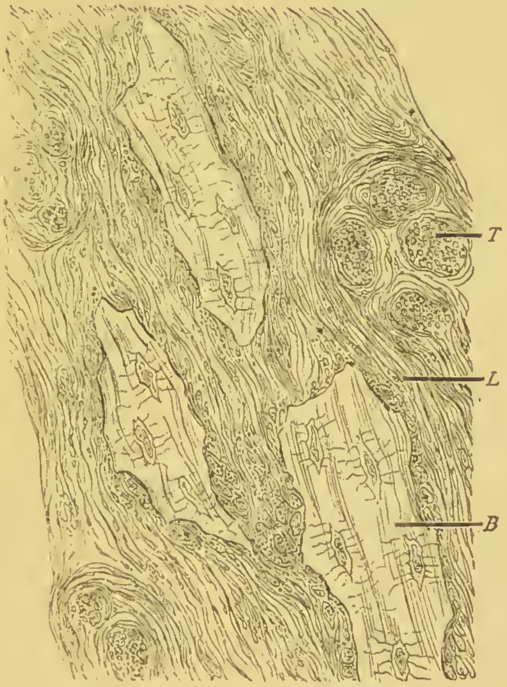
EBURNIFICATION.—SECTION OF A PULP-STONE OF A LOWER MOLAR.

L, lamellated secondary dentine, traversed by radiating dentinal canaliculi; *C*, *C*, globular masses, exhibiting a concentric striation. Magnified 300 diameters.

2. So-called "pulp-stones" composed of regularly-developed

laminated bone. I have, as mentioned before, examined pulps composed almost exclusively of a dense fibrous connective tissue, the bundles of which were so interlaced in all directions as to establish a regular cicatricial connective tissue. Scanty nerve-bundles and blood-vessels traverse the dense connective tissue, which in some places appears to be more or less crowded with medullary or inflammatory corpuscles. In such fibrous pulps I have observed smaller or larger masses of fully-developed bone-tissue, composed of more or less regular lamellæ, or of calcified fibrous lamellæ. In these a large number of irregular branching bone-corpuscles are seen, arranged in rows or chains, where the basis-substance shows a more fibrous character. Sometimes the bone-tissue appears in lamellated islands, sharply marked from the surrounding fibrous tissue. No formations of secondary dentine were combined in these cases with the bone-tissue.

FIG. 174.



OSSIFICATION.—SECTION OF PULP OF UPPER LATERAL.

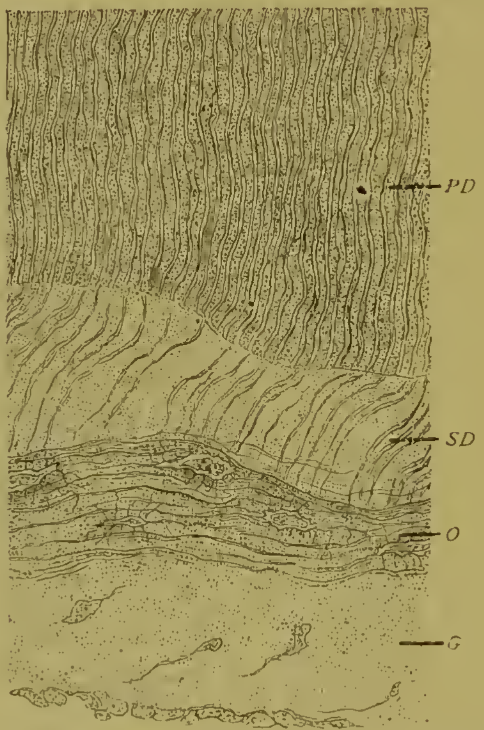
L, longitudinal, *T*, transverse bundles of cicatricial fibrous connective tissue; *B*, spicula of lamellated bone. Magnified 500 diameters.

3. So-called "pulp-stones" composed of a mixture of regular bone and dentinal tissue. In rare instances I have met with pulp-stones partly composed of secondary dentine and lamellated bone in such a way that irregularly-bounded masses of

bone contained a few large bone-corpuscles, alternately surrounded by a basis-substance, which contained only irregular, wavy, dentinal canaliculi.

4. So-called "pulp-stones" composed of dentine with the features of primary dentine. I have examined a large number of pulp-stones; one of them, a mass about the size of a pea, was built up of dentine. The canaliculi of this dentine are perfectly parallel, and between these a finely-reticular basis-substance was found, arranged in the same way as in primary dentine of temporary teeth of children, which teeth are generally poorly supplied with lime-salts. In this specimen, too, the dentinal canaliculi are wide; the basis-substance between them, on the contrary, is narrow. The dentinal fibers are relatively bulky beaded formations, with numerous large conical spokes penetrating the peripheral space of the canaliculi. This regular dentine toward the periphery of the pulp-stone is bounded by a slightly-fluted contour, a narrow zone of which exhibits the

Fig. 175.



Dentinification.—Section of Pulp-Stone of Upper Molar.

PD, primary dentine; *SD*, secondary dentine; *O*, irregularly-lamellated bone-tissue; *G*, granular layer toward the pulp-tissue. Magnified 500 diameters.

structure of canaliculated secondary dentine. This zone blends with a still narrower one, which is composed of an indistinctly lamellated bone-tissue, wherein bone-corpuscles, large in size but few in number, are imbedded. This layer is followed by the bounding layer of the specimen. The latter, which has a granular appearance, contains a few angular or spindle-shaped protoplasmic bodies and a few dentinal canaliculi.

CHAPTER XXVII.

MECHANICAL ABRASION.

This term is applied to the process in which the teeth suffer loss by attrition. Mechanical abrasion is a result of imperfect articulation, advanced age, or of an imperfect calcification of the enamel and the dentine of the teeth. Under normal conditions the cuspid, the bicuspid, and the molar cusps fit accurately into the depressions of the teeth in the opposite jaw. Even upon the incisor teeth, when they are first shed, especially on the lower ones, we notice three protuberances, which, through wear, soon disappear. In a normally articulating set of teeth, the cusps of the bicuspids and molars are not easily worn off, and the incisors and cuspids are almost entirely relieved of wear, so that we sometimes meet with persons fifty years of age who still have the enamel upon the cusps of their teeth preserved. As a rule, however, most people lose some of their molar teeth before their thirtieth year. The consequence of the loss of teeth out of the dental arch is a contraction of the jaw, and if one or two of the back teeth be lost from the same side of one jaw, the result will be an imperfect articulation, unless the corresponding teeth be removed from the jaw opposite. In correcting protrusions of either the upper or the lower jaw, it sometimes happens that we need only remove the corresponding two upper or lower first permanent molars.

Frequently we see that where a few years ago a single molar or bicuspid has been removed from either the upper or the lower jaw, the subsequent contraction of the dental arch has almost closed up the gap. In the displacement of the remaining back teeth, the points of the cusps come in contact with one another, and are consequently worn off; and correspondingly, as the two jaws come closer together, the upper front teeth are worn out on their lingual surfaces. After the enamel of a molar tooth has been worn off, the dentine wears away much faster than the enamel does. Where formerly the cusps of the tooth were situated, we now see depressions in the dentine. Later on, again, when the grinding-surface of the tooth has lost all the enamel of its fissures, the dentine is eroded much faster than the enamel that still surrounds the crown. In such cases a molar tooth presents a cup, the dentine in the center sometimes being worn away up to the pulp-chamber, while the surrounding enamel of the tooth forms a more or less sharp, ragged, high ridge. In a few instances only the enamel of the labial surfaces of the upper incisor teeth is left, while the enamel of the labial surfaces of the corresponding lower incisors is lost.

Occasionally we see persons who have lost one or two teeth of the upper jaw before the tenth or twelfth year of age, in consequence of which the upper jaw is retracted while the lower one continues to develop. In such cases a protrusion of the lower jaw gradually follows, and the teeth then articulate only at their cutting-edges and the points of their cusps. In such an abnormal articulation, the person acquires a habit of using the lower jaw in a rotary movement, by means of the pterygoid muscles. The antagonizing teeth then wear upon one another, so much so that in a few years the cusps disappear, and the incisors sometimes become worn down to the gum, presenting a more or less flat, smooth grinding-surface, similar in shape to that of a worn-off bicuspid. Smokers who use clay pipes, holding them mostly between the same teeth, often exhibit on these teeth abraded notches of a shape fitted to the pipe-stem.

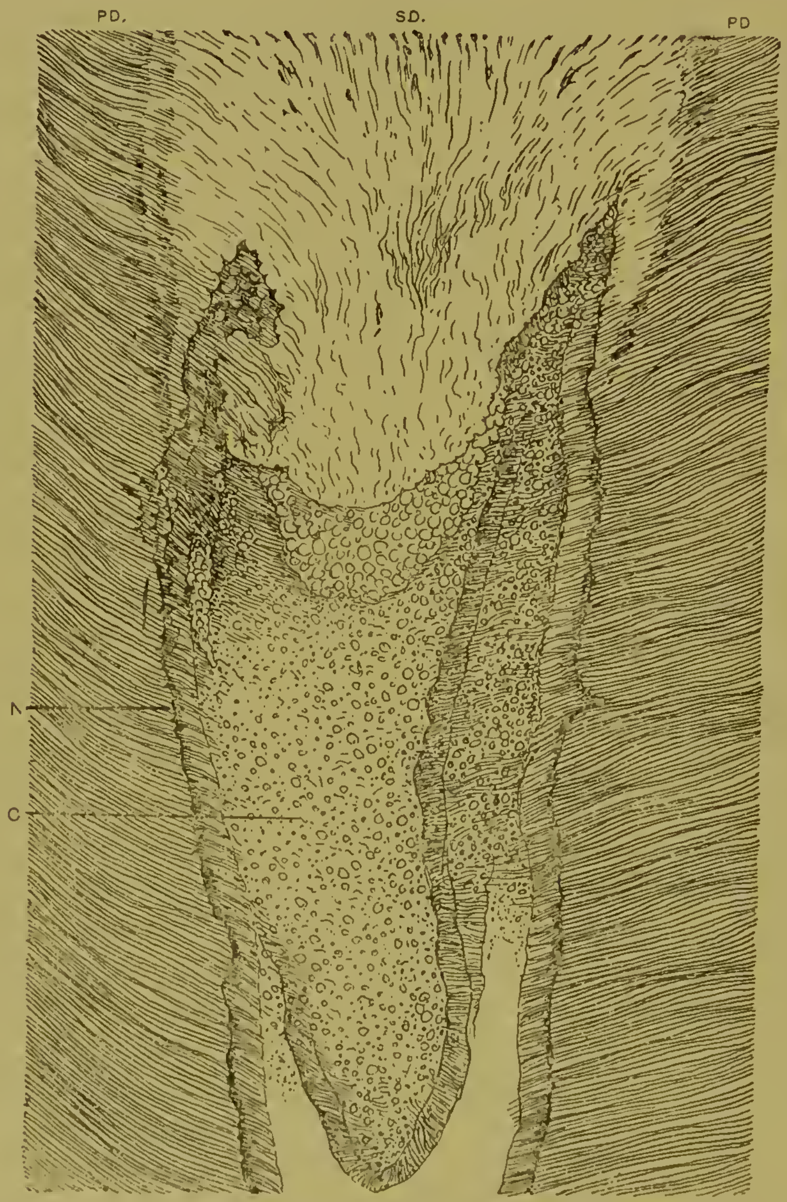
In mechanical abrasion, much depends upon the hardness of the teeth, as well as the kind of food used by the individual. R. Baume states that some savage tribes add sand to their food, which wears their teeth away in early life. Other persons, and especially highly civilized people, prepare their food in such a manner that the teeth are called upon to do but little mastication, in which case the enamel upon the cusps remains intact to the fiftieth year of age or even longer. Wherever the tooth loses its enamel, it becomes sensitive to the action of weak acids, to thermal changes, and, more or less, to mastication. The degree of the sensitiveness of the abraded surfaces, however, mainly depends upon the chemical composition of the fluids of the mouth. Saliva, when of a distinct acid reaction, always causes considerable sensitiveness of these surfaces.

As to the pathology of mechanical abrasion, little can be said. Both ground specimens and those obtained after decalcification in chromic-acid solution show abrupt terminations of the enamel-prisms as well as of the dentinal canaliculi, without a trace of reaction. Occasionally along the border of the abraded surface a narrow zone of decalcification, parallel to the contour of the abrasion, is seen. In specimens treated with a solution of ammoniacal carmin, the decalcified zone assumes a saturated pink color. I have tried to stain a number of ground specimens of teeth affected by mechanical abrasion, with solution of chloride of gold, followed by decalcification in a six per cent. solution of glacial acetic acid. All these experiments failed, because before the calcified dentine had more than begun to exhibit the details of its structure, the decalcified zone was already of a deep violet, nearly black color, that precluded the study with even medium powers of the microscope. The presence of a decalcified zone close beneath the abraded surface sufficiently explains the intensified sensitiveness of the dentine of the affected tooth.

Of considerable interest is the formation in the pulp-chamber of secondary dentine, always corresponding in site to the abraded surface. In the chapter on secondary dentine the statement has been made that mechanical abrasion is a common cause of the formation of secondary dentine. Here I wish to draw attention to peculiar varieties in the appearance of secondary dentine. Fig. 176 illustrates such a formation of an unusual type. Whereas the upper portion of the pulp-chamber is filled with secondary dentine, scantily supplied with irregular and wavy canaliculi, the lower portion exhibits a zone of secondary dentine parallel to the primary dentine, but not as yet calcified, as is proven by a deep stain of ammoniacal carmin. The central portion of the pulp-chamber exhibits an ill-calcified peg of secondary dentine, with but scanty canaliculi and granular deposition of lime-salts.

Fig. 177 shows peculiarities in the arrangement and course of the dentinal canaliculi. In the uppermost layer the secondary dentine is thoroughly calcified and conspicuous only because of the bifurcation and the spindle- and pear-shaped widenings of the dentinal canaliculi. In the following layer we see a formation of secondary dentine, not as yet calcified, but holding a limited number of calcareous globules, the so-called "*calco-globine.*" The fluted contours within this layer indicate the successive formation of the basis-substance in a manner similar to the normal development of dentine in a fœtus. The midmost portion of secondary dentine is marked by a devious course of the dentinal

Fig. 176.



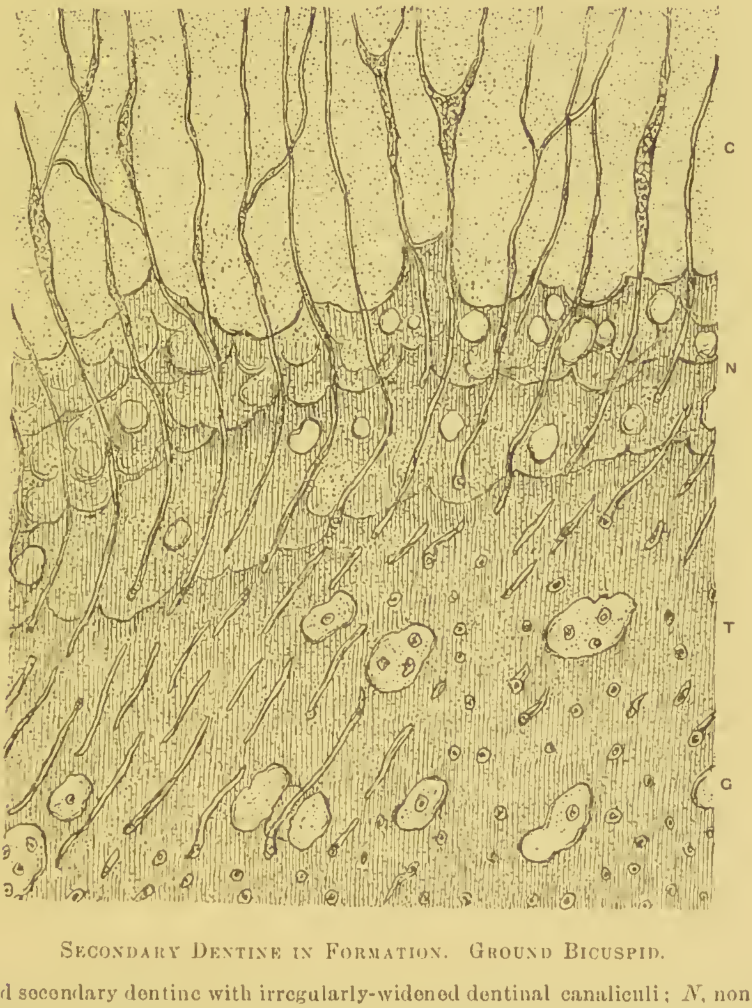
Ground Molar. Formation of Secondary Dentine in consequence of Mechanical Abrasion.

PD, primary dentine; *SD*, secondary dentine; *N*, non-calcified zone of secondary dentine; *C*, partly calcified secondary dentine. Magnified 100 diameters.

canaliculi, which, in the same field, run obliquely and transversely. Around one or several dentinal canaliculi we find lime-salts deposited in such a manner that the nomenclature of territories which we have adopted in our history of the development of dentine once more becomes justified.

Fig. 178 is taken from another tooth of the same patient. It shows a successive calcification of the basis-substance of the secondary dentine, always in the shape of calcareous globules, partly isolated, partly confluent. The isolated globules are mostly pierced by a dentinal canaliculus, which fact again proves the propriety of our views concerning the production of terri-

FIG. 177.



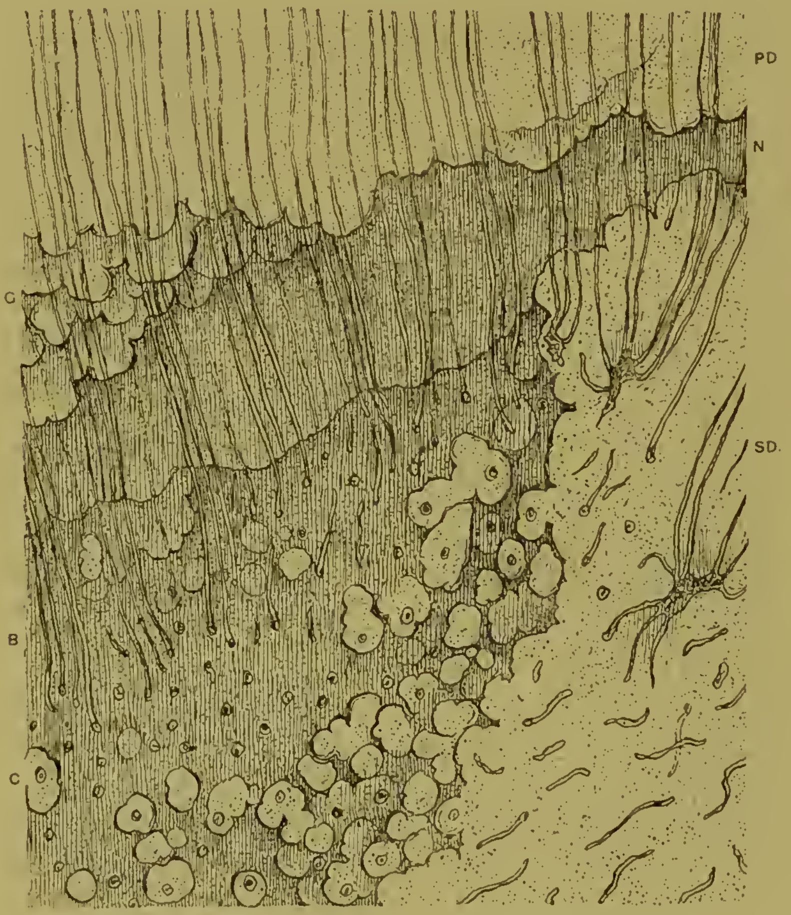
SECONDARY DENTINE IN FORMATION. GROUND BICUSPID.

C, calcified secondary dentine with irregularly-widened dentinal canaliculi; *N*, non-calcified secondary dentine, deeply stained with carmin, holding scattered calcareous globules; *T*, transverse section of secondary dentine and its canaliculi; *G*, calcareous globules. Magnified 500 diameters.

tories around the dentinal canaliculi. A portion of the secondary dentine exhibits branching protoplasmic bodies, similar to bone-corpuscles, the offshoots being in this instance dentinal canaliculi partly in connection with those of the primary dentine.

A rather unusual occurrence is depicted in Fig. 179. The primary dentine is succeeded by a non-calcified layer of secondary dentine, the most conspicuous feature of which is that its dentinal canaliculi are arranged in groups or bundles, between which bundles the basis-substance is altogether devoid of canaliculi. This is followed abruptly by a layer in which the grouping of the dentinal canaliculi is shown in a transverse section.

Fig. 178.

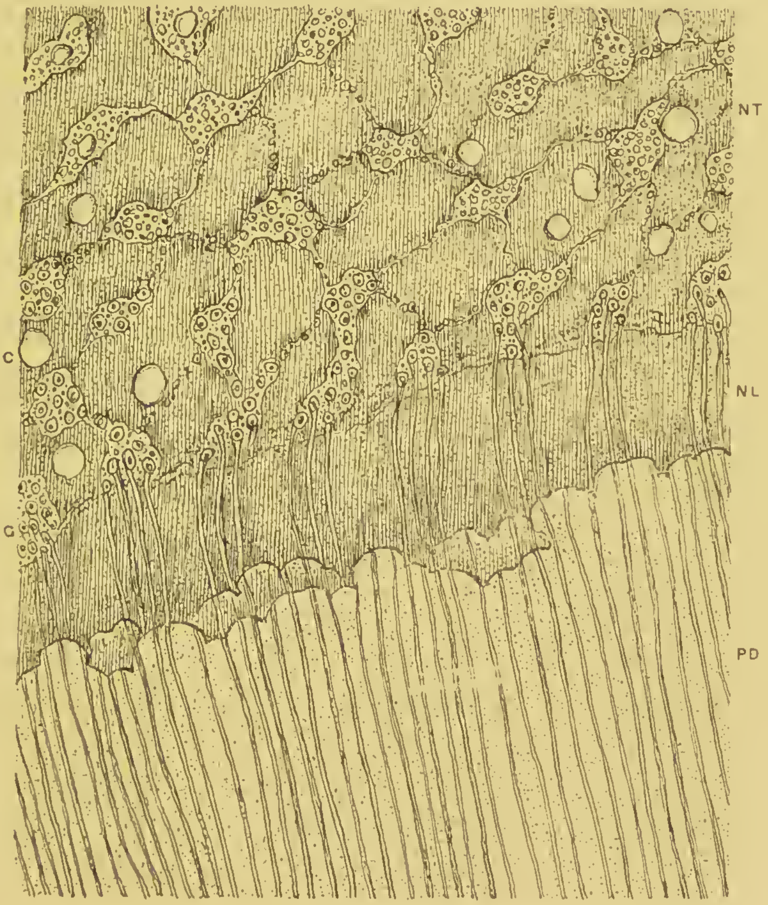


Secondary Dentine in Formation. Ground Bicuspid.

PD, primary dentine; *SD*, secondary dentine; *N*, non-calcified secondary dentine containing dentinal fibers in bundles; *G*, globular deposition of lime-salts, advancing from the primary into the new calcified secondary dentine; *B*, non-calcified basis-substance, holding scattered calcareous globules; *C*, calcareous globule pierced by a dentinal canaliculus. Magnified 500 diameters.

Their bundles are here arranged in fields, branching and interconnecting, much resembling the protoplasmic net-work of myxomatous connective tissue. The only difference is that instead of the so-called granules,—or, rather, points of intersection of the reticulum of living matter within the protoplasm,—bundles of dentinal canaliculi have appeared. The basis-substance filling the meshes of this remarkable reticulum is devoid of canaliculi, holding only a few scattered calcareous globules. This specimen, though anomalous, plainly shows the interchangeability of all varieties of connective tissue. The form may change; the type remains.

FIG. 179.



SECONDARY DENTINE IN FORMATION. GROUND BICUSPID.

PD, primary dentine; *NL*, non-calcified secondary dentine in longitudinal section; *NT*, non-calcified secondary dentine in transverse section; *G*, groups of dentinal canaliculi in transverse section; *P*, protoplasmic spaces, holding dentinal fibors in transverse section; *C*, calcareous globule. Magnified 500 diameters.

CHAPTER XXVIII.

EROSION.

THIS term is applied to a process in which the hard dental tissues are eaten or wasted away, principally upon the labial surfaces near the cervical margins of the teeth. Some of the older writers have applied the name of *denudation* to this process, but at present *erosion* is universally used. Erosion was noticed as early as 1778 by J. Hunter; but the first investigator who gave a reasonable explanation of it was E. C. Kirk, who, in a paper read before the First District Dental Society of New York, in 1886,[*] demonstrated that its origin was from acid mucoid secretions of the mouth. He, however, gives the credit of priority to J. Truman. Much was written on this subject, but without advancing anything new, till E. T. Darby, in a paper read before the New York State Dental Society, May, 1892,[†] stated that erosion is mostly found in teeth of patients who suffer more or less from gout. S. G. Perry, in an article read before the New York Odontological Society, 1893,[‡] corroborated the assertion of E. T. Darby, and proves from experiments made on himself that most cases of erosion yield to an anti-gout treatment.

In regard to the etiology of erosion, there are three main theories: first, that the cause is *mechanical* action wrought by the too frequent use of the tooth-brush in combination with gritty dentifrices; second, that the cause is *local acidity of the mouth*, produced by acid beverages; third, that it is *constitutional acidity of the mouth* as produced in gout. The latter theory is the most generally accepted and most plausible one, although we meet with many gouty patients whose teeth are not affected by erosion. Again, it cannot be denied that by the too vigorous use of the tooth-brush the cementum, the dentine, and the enamel, especially when softened by an acid, may, to a certain extent, be brushed away. But as we meet with erosion upon the approximal and lingual surfaces of the teeth, the mechanical theory cannot be correct. We have therefore to admit that erosion is not, as yet, explainable in a satisfactory manner. It is generally acknowledged that in gouty diathesis there exists in the system a superacidity, especially of uric acid. This acidity, through the circulation of the blood, where it exists in combination with other salts, may be imparted to the secretions of the mouth, in which case the occurrence would be explicable. Gouty conditions of the system may be due to heredity, or they may be produced by improper food and too little exercise in the fresh air. S. G. Perry, in his article (*l. c.*), quotes Dr. J. M. Fothergill, who is of the opinion that a gouty diathesis of the system depends upon imperfect conditions of the liver. Dr. Fothergill distinguishes two kinds of gout: one, when a person who has lived too luxuriously for a number of years gets *rich man's gout;* the other, when a person born with an imperfect liver, and not taking exercise enough in the fresh air to consume even a small quantity of nitrogenized food, gets *poor man's gout.* The writer himself has observed patients who suffer from both kinds of gout, and who state that whenever their teeth become sensitive they know that they are about to have an attack of this disease. On the other hand, I know of quite a number of patients who suffer from gout, but their teeth do not show erosions. This theory, therefore, although plausible, is by no means a finality. So much is certain, however: that erosion is due to the action of an acid, —probably lactic acid. It was also supposed that the living matter of the tooth could produce the reaction; but as both living and devitalized teeth are affected in a similar manner by this destructive process, this theory is not tenable.

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[*] *Dental Cosmos*, 1886.

[†] "Dental Erosion and the Gouty Diathesis: Are they Usually Associated?" *Dental Cosmos*, 1892.

[‡] "Erosion of the Teeth." *International Dental Journal*, 1893.

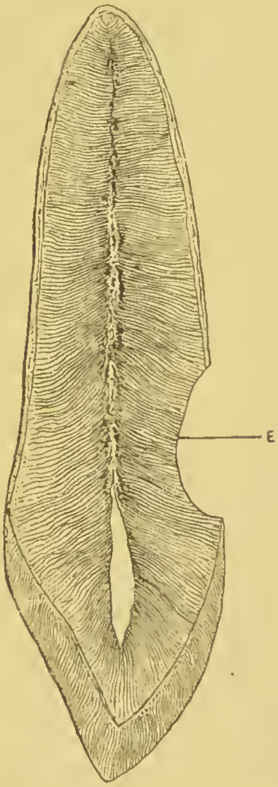
There are a number of cases on record of *chemical abrasion*, so termed, of which the writer has seen two in his own practice. Both had the characteristics of erosion, although the labial surfaces of the teeth showed but little of this process, while the cutting-edges of the incisors and cuspids, especially the upper ones, were more than half dissolved away. The teeth were similar in appearance to those affected by mechanical abrasion, but as the lower teeth did not articulate with the upper ones, mechanical abrasion in their case was out of the question.

In regard to the pathological anatomy of erosion, there is but little to say. As the appearances of the eroded dental tissues under the microscope are similar to those affected by mechanical abrasion, I refer the reader to Chapter XXVII, in which that topic is considered.

Erosion mostly appears in persons over thirty years of age, and starts in one or more small pits, or a slight groove near the cervical margin, in the cement of the neck of the tooth. Usually the attack is upon the labial surfaces; sometimes it is noticed upon the approximal surfaces; but quite rarely on the lingual surfaces of the teeth. The eroded places mostly are smooth, and have a polished appearance. Often these grooves start in the enamel of the labial surfaces of the teeth, a little distance away from the gum, presenting a single, or sometimes a double, furrow which runs parallel to the cutting-edges of the teeth. In rare instances, we notice the greater portion of the enamel of the labial surfaces of the incisors dissolved. All the eroded surfaces are sharply defined; that is, the boundary is surrounded by a sharp border, whether of enamel or cementum. We also meet with eroded surfaces, the outlines of which, under the microscope, look fluted or slightly bay-like. This appearance has induced some writers to believe that the destructive agent of erosion was the so-called *Howship's lacunæ*, or *giant-cells*. These fluted outlines are mostly found in ill-calcified teeth, and again prove that the dentine and the cementum are dissolved in the same manner in which they are built up,—*i.e.*, by territories. Erosion usually commences on the upper or lower cuspids, probably because these teeth are generally the first that suffer from recession of the gums. It has been stated that erosion occurs below the margin of the gum, but the writer has not met with a single case in which erosion was not preceded by a corresponding recession of the gum. Although there are cases of erosion which are seen to extend beneath the gum-margin, in these instances we always notice an inflammation which has produced a slight tumefaction of the gingival border, thereby overlapping the eroded surface. The cuspids occupy the most prominent position in the dental arch, and consequently are the most subject to irritation by the tooth-brush, which probably accounts for the early recession of the gums on the labial surfaces of these teeth. The next teeth affected by erosion are most commonly the first and second bicuspids: then the incisors; and, lastly, but not often, the molars. When erosion has affected most of the teeth in the dental arch, usually the cuspids, and especially the upper ones, contain the deepest defects; next the bicuspids; and then the incisors: while the defects upon the buccal surfaces of the molars are rarely large.

As the eroded surfaces increase in extent, they assume an appearance as though they had been made by means of a small three-cornered or round file. (See Fig. 180.) The surfaces are generally smooth and bright, but in some few cases dull and rough. The roughness usually is due to the commencement of caries. The color of the eroded tissues, at first, is white or yellowish-white in the enamel, and a light yellow in the dentine and the cementum; but later on it changes in the latter two tissues to a dark yellow or even dark brown. The eroded surfaces are usually soon discovered by the patient, especially during the act of brushing the teeth, or when a foreign substance, such as a tooth-pick, a pin, or the nail of a finger, is brought in contact with the erosion. When this process is active, the affected dentine, the cementum, and sometimes the enamel are extremely sensitive; while as soon as the secretions of the mouth attain a neutral or an alkaline reaction, the eroded surfaces lose their sensitiveness, and the process comes to a standstill.

FIG. 180.



GROUND SECTION OF AN UPPER LATERAL INCISOR, WITH EROSION.
E, erosion at the labial aspect of the neck. Magnified 4 diameters.

Erosion, therefore, cannot be arrested by the introduction of filling-materials into the eroded cavities; on the contrary, we frequently observe the gold fillings in the cervical portions of the teeth stand above the level of the enamel for a considerable height. In some instances, however, the eroded surfaces become attacked by caries, in which case the filling of these places becomes a necessity. As stated above, when the eroded surfaces begin to decay, we first notice a roughness, and afterward a softening, which is characteristic of caries. When the carious process is an acute one, the color of the eroded surfaces may remain yellowish-white or even white, and in these cases caries is apt to be confounded with erosion. In the majority of instances, however, the caries preceded by erosion is of a dark-yellow or a brown color, and not easily mistaken for erosion.

CHAPTER XXIX.

THE REACTION OF THE DENTINE UPON FILLINGS.

During the past sixteen years, for the purpose of procuring trustworthy data as to the reaction of various filling-materials upon the hard tissues of the teeth, I have made a number of experiments in their introduction, mainly upon the temporary teeth of my own sons. Accurate notes as to conditions and dates were kept, so that the history of each experiment, including the time the filling remained in the cavity, was complete. I came into possession, also, of a number of teeth from patients, into which fillings had been introduced on account of caries in the ordinary course of my practice. Altogether, there were somewhat more than fifty teeth, of each of which I knew the exact history.

Some of these teeth were ground into thin slabs under the precautions mentioned in the chapter on dentine, the most important of which is not to allow the slab to become dry, even for a moment, during the process of grinding. Others were placed in a one-half of one per cent. solution of chromic acid, which was renewed daily for about one week. These teeth were kept for several years in separate jars, the solution being changed about three times a year. For some time, about two weeks before cutting, the one-half of one per cent. solution of chromic acid was renewed daily, at the end of which time the teeth had become softened so as to be fit for cutting with the microtome.

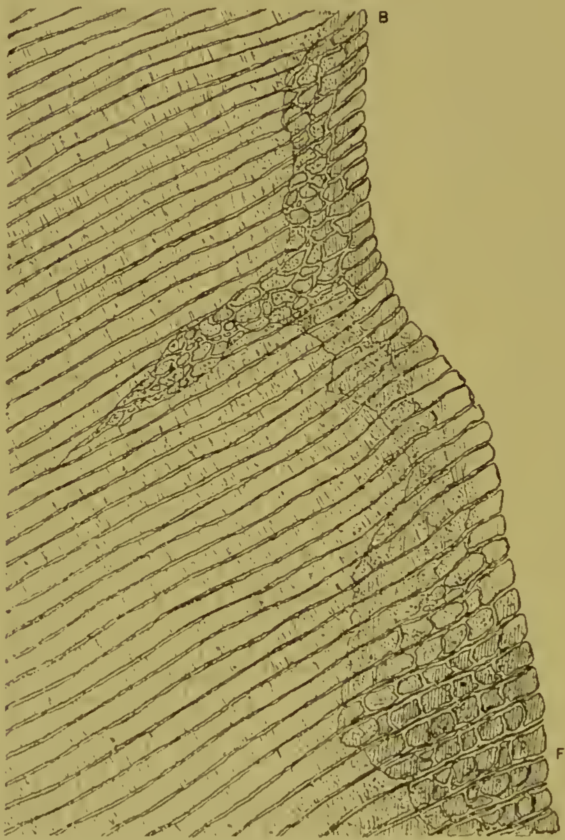
The deeper layers of the dentine needed decalcification in most cases, even after imbedding in celloidin.

The protracted exposure to the decalcifying agent effected a surprising result upon the enamel-tissue, for, whereas in previous years I had invariably met with failure in decalcifying this tissue, I now succeeded in decalcifying the enamel of both temporary and permanent teeth.

Many of my specimens show varying spaces of thorough decalcification, but it never involves the enamel *in toto*. What I have stated with regard to the structure of enamel-tissue in Chapter XI, I found corroborated in these specimens, made for an entirely different purpose from those of former experiments. The mere fact that enamel can be partially, at least, decalcified and preserved, shows plainly the error in the view still held by some, that enamel is not a tissue, but a coat of mail entirely destitute of properties of life.

In analyzing the results of fillings, I wish to draw attention to several possible sources of error which must constantly be borne in mind to prevent faulty conclusions. First, it is not always easy to determine the exact location of the previous filling at the border of the cavity, since crevices sometimes appear in the margin of an aspect resembling that of a previously-filled cavity. The border of the dentine is, as a rule, easily recognizable by the presence of a film of enamel, or, where this is missing, by the bay-like excavations present in the interzonal layer between dentine and enamel. A second source of mistake is the presence of portions of dentine decalcified before being placed in the chromic-acid solution. Such fields, in specimens stained with an ammoniacal solution of carmin, are recognizable by a green color, which is due to the reduction of the chromic acid to chromic oxide. It is considered a legitimate procedure to introduce fillings into cavities in the dentine even though the deeper portions of the cavity be slightly discolored, rather than to expose a pulp. Moreover, small carious places in the dentine or enamel cannot always be detected in a cavity of a tooth with the naked eye, or even with a simple magnifying lens. In such a case, under the microscope, the impression may be conveyed to the observer that he sees reaction processes in the dentine where, in fact, only vestiges of the previous process of caries are present. *F*, *B*, Fig. 181, affords an illustration of this statement. Along the border of a cavity of the tooth which was filled with gold April 22, 1889, and extracted on account of pericementitis April 26, 1893, a process is seen, which was first described by Abbott as inflammation

FIG. 181.



AMELITIS—INFLAMMATION OF ENAMEL AT THE BORDER OF A GOLD-FILLED CAVITY.

B, border of cavity; *F*, prisms broken up to medullary corpuscles, enamel-fibers enlarged. Magnified 500 diameters.

of the enamel, *amelitis*, due to caries. The enamel-prisms are broken up into small squares, or reduced, as it were, to their embryonal state. More than that, the enamel-fibers between the broken-up prisms are slightly enlarged. I cannot reasonably attribute this change to the presence of the gold filling, since not even dentine shows so pronounced a reaction after the introduction of gold fillings.

There are two possible explanations of the amelitis in this case: either we have before us vestiges of primary caries of the enamel, or the enamel has been attacked by secondary caries.

A third source of error is found in the fact that practitioners commonly apply to the walls of an excavated cavity strong aseptic coagulants, such as pure carbolic acid, creasote, a solution of corrosive sublimate, etc., before introducing the filling. Thus the tissues along the border of the cavity are rendered dead to a certain depth. This is shown, under the microscope, by a green color along the border of the cavity and a shriveled, granular appearance of the dentinal fibers to a certain depth of the tissue, when normal fibers again reappear. That under these conditions no reaction of the filling-material can be expected along the border of the cavity is plain enough.

Having enumerated the points to be kept in view, I now proceed to the analysis of the specimens.

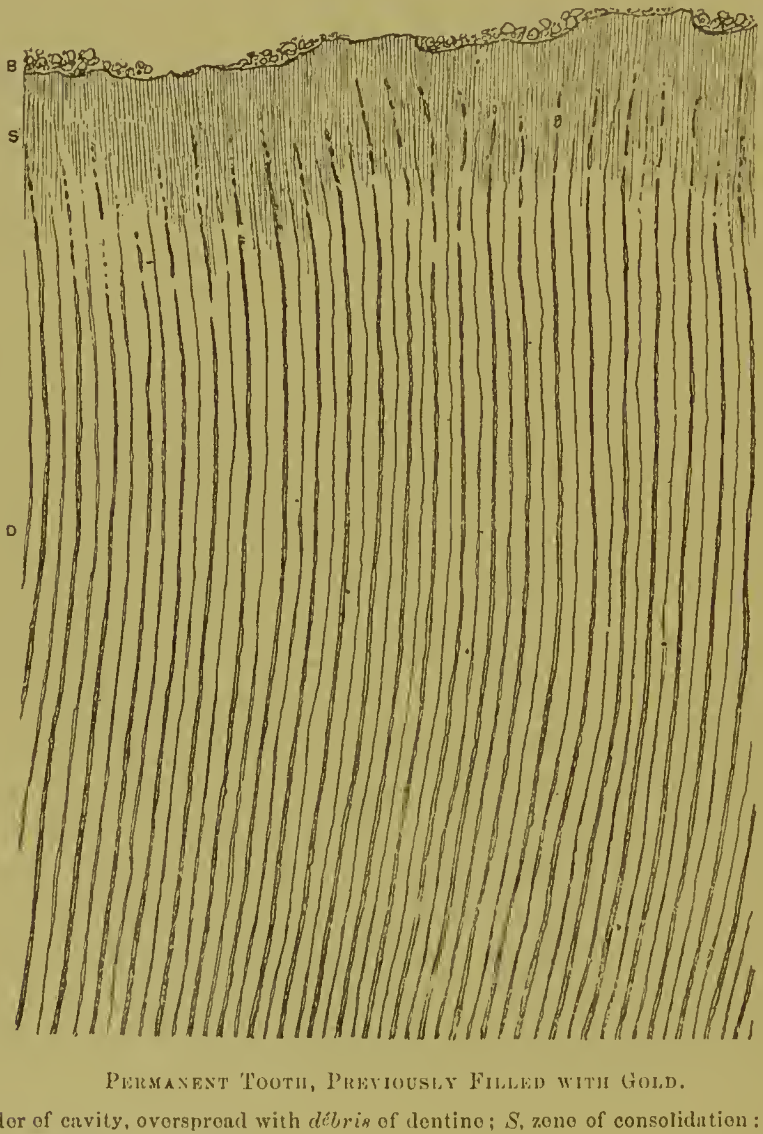
I. Gutta-percha.—This never showed the slightest reaction at the border of the cavity in the dentine. The dentinal canaliculi and their tenants terminate abruptly toward the cavity. Only here and there was seen a green discoloration at the border,—due, probably, to coagulants applied before the introduction of the filling.

II. Gold.—In some instances no reaction was noticeable in the dentine, only a zone of green color, attributable to causes just mentioned under gutta-percha. In other instances, there is a distinct reaction along the border, as illustrated in Fig. 182. The dentine is so thoroughly consolidated in the zone nearest the cavity that this portion shows no dentinal canaliculi. The latter stop short, the termination being evidently due to an obliteration of the canaliculi, at first partial and finally complete. The solidified zone of dentine is still alive, judging from the slight stain present of the ammoniacal solution of carmin. In still other instances the gold filling has led to a partial obliteration of dentinal canaliculi similar to that induced by oxyphosphate of zinc, though never as complete as that which follows the introduction of the last-named filling-material.

III. Oxyphosphate of Zinc.—The reaction is almost constantly present, and consists of a solidification of the dentine and an obliteration of a number of dentinal canaliculi. The dentinal canaliculi which are obliterated under oxyphosphate fillings first become faint, scarcely traceable, and ultimately disappear, in consequence of which disappearance the fields of basis-substance between the dentinal canaliculi are considerably broadened.

The ramifications of some of the dentinal canaliculi seen in Fig. 183 are made explicable by the presence of lateral offshoots of the dentinal fibers, some of which become conspicuous in consequence of irregularity in the process of consolidation. The consolidation is densest along the border of the cavity, where dentinal canaliculi are quite scanty; but the consolidated dentine extends to a considerable depth before it blends with normal dentine.

Fig. 182.



Permanent Tooth, Previously Filled with Gold.

B, border of cavity, overspread with *débris* of dentine; *S*, zone of consolidation; *D*, normal dentine. Magnified 500 diameters.

IV. Amalgam.—The features that appear after the introduction of this filling depend upon the length of time the material is left in the cavity. A few months after its introduction a pronounced discoloration of the border of the cavity is almost invariably visible. This is due to the penetration of silver or mercuric sulphide into the dentinal canaliculi. The metallic

FIG. 183.

GROUND BICUSPID, PREVIOUSLY FILLED WITH OXYPHOSPHATE OF ZINC.

B, border of cavity; *D*, normal dentinal canaliculi; *O*, obliterated dentinal canaliculi. Magnified 500 diameters.

particles are black under the microscope, and therefore easily recognizable. They seem to be carried into the depths of the dentine for some distance, by contractions of the dentinal fibers; otherwise it would be inexplicable that the most deeply-stained discoloration is seen at some distance away from the border of the cavity. (See Fig. 184.)

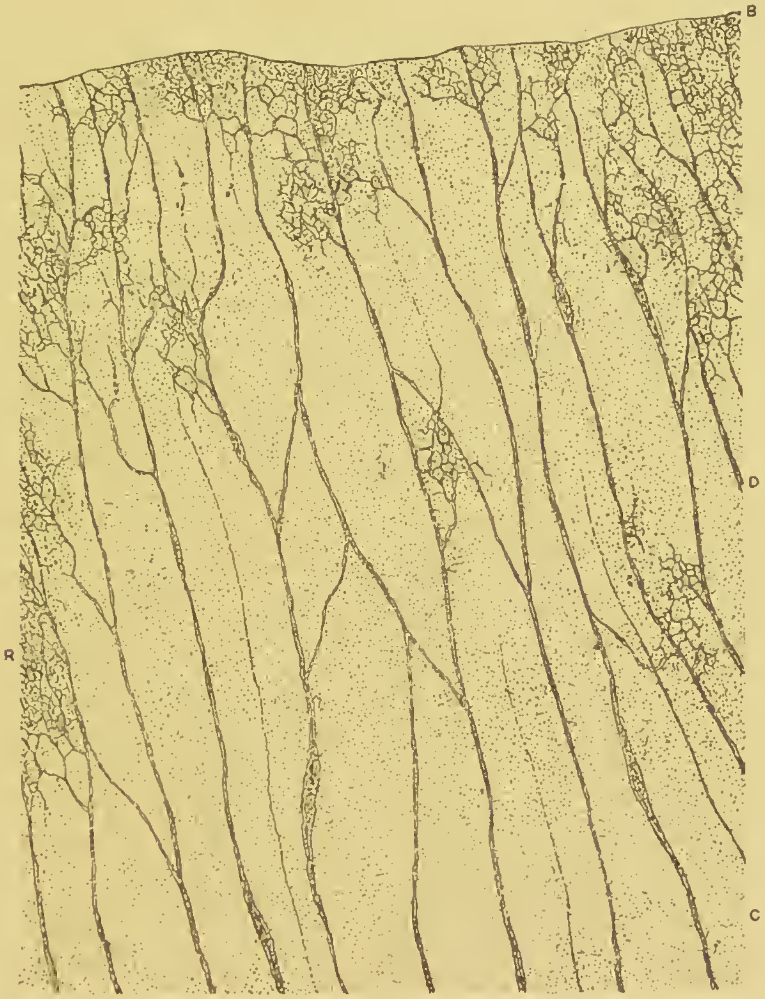
Fig. 184.

Ground Tooth, Previously Filled with Amalgam.

S, surface of filled cavity marked by large metallic clusters; *D*, dentinal canaliculi holding rows of metallic particles, the reticulum quite pronounced in a few places; *P*, darkly pigmented zone; *L*, slightly pigmented portion of dentine, followed by a darker pigmented portion farther below. Magnified 500 diameters.

The accumulation of the metallic granules is sometimes an excellent means of rendering visible the minute structure of the dentine. In the highest degree of infiltration not only the dentinal fibers and their coarser offshoots, but also the finest reticulum of the living matter in the basis-substance is strongly defined in black. In Figs. 51 and 52, in the chapter on "The Minute Structure of Dentine," this effect upon the reticulum is illustrated. Discoloration after the introduction of amalgam becomes less noticeable in the vicinity of the cavity in proportion to the lapse of time after its introduction. On the other hand, the body of the tooth in time assumes a dark hue. This fact becomes explicable when we recognize the gradual diffusion of the metallic particles throughout the dentine. Tin fillings behave similarly to amalgam, only in a less pronounced degree.

FIG. 185.



DECALCIFIED TEMPORARY TOOTH, PREVIOUSLY FILLED WITH AMALGAM.

B, border of cavity; *D*, dentinal canaliculi of varying calibers, holding metallic granules; *R*, reticulum in the basis-substance; *C*, broad fields of recalcified basis-substance. Magnified 500 diameters.

After the lapse of several years the reaction of amalgam upon the adjacent dentine is quite marked. It consists in a consolidation of the dentine, due to a partial obliteration of the dentinal canaliculi and a simultaneous broadening of the fields of the basis-substance. (See Fig. 185.)

The apparently devious courses of some of the dentinal canaliculi become comprehensible upon the grounds stated in the paragraph concerning oxyphosphate of zinc. Some of the lateral coarse offshoots of the dentinal canaliculi have been made conspicuous by the preceding decalcification, and have remained unchanged, though many of the main canaliculi or portions of them have become obliterated. That the recalcification is not a perfect one is best evidenced by the varying calibers of the dentinal canaliculi and the presence of the delicate reticulum of living matter in the basis-substance, which is the more conspicuous the nearer it approaches to the border of the cavity. All the formations of living matter in such specimens —the dentinal fibers as well as the minutest reticulum—contain tiny particles of sulphuretted metal, though nowhere in large numbers.

From the above facts we may draw the following practical conclusions: For all teeth in which the hard tissues are much softened, owing to constitutional difficulties, and where irritation of the living matter is to be prevented, gutta-percha will prove to be the best filling-material. Oxyphosphate of zinc will be found preferable in fairly good teeth which have become softened through caries or temporary illness. Gold produces a reaction in the dentine in some instances; in others it does not. It is best adapted for adult and well-calcified teeth. Amalgam ought to be used in exceptional cases only. Although these rules may hold good for general practice, in the majority of instances the practitioner must be guided by the circumstances of the case and his own experience. It is important, however, to remember the fact that the application of pure carbolic acid mummifies, so to speak, the living matter in the dentine of the cavity to a slight depth. This action will render the dentine less sensitive to thermal changes, and make the walls of the cavity aseptic.

CHAPTER XXX.

HYPEROSTOSIS OF ROOTS OF TEETH.*

"UNDER the term hyperostosis† I propose to consider all the forms of pathological new growths of cementum, including what authors are wont to term osteoma, exostosis, hypertrophy of the cement, etc.

"As to the cause of this not very infrequent disease, the following points may be enumerated:

"A. Direct irritation of the pericementum through slight long-standing caries of the crown or neck; or, exposure of the pulp, mainly the result of caries;

"B. Localized irritation of the pericementum of constitutional origin, such as from gout and syphilis;

"C. Irritation of the pericementum of upper teeth after the removal of their antagonizing teeth of the lower jaw, the result of, or induced by, gravitation.

"Obviously, irritation of the pericementum is considered by all authors as the cause of outgrowths of cementum.

"That a chronic irritation of the pericementum, whatever the cause may be, may result in a new formation of cementum, nobody will doubt; nay, it has been clearly proven by Bödecker that a circumscribed hyperostosis of the cementum may arise from chronic pericementitis. The question, however, is, Can a diffused enlargement of the cementum occur in consequence of pericementitis, either of a local or constitutional origin, after the cementum has once been fully formed? This question I feel constrained to answer in the negative, and I base my opinions upon microscopical studies of such tumors. My conviction is that hyperostosis of cementum of a diffused character is *in most instances a fœtal malformation.*

"If a carious tooth be extracted, and the roots be found in a hyperplastic condition, the first impression, of course, would be that the inflamed pulp, in this case, has led to pericementitis, and the latter to hyperostosis of the roots. This undoubtedly in some instances may be the case, more especially when the process of caries has attacked a lateral surface of the crown or the neck of a molar, and the root or roots nearest to the point of irritation of the pulp are found to be enlarged; but if all the roots of a molar are uniformly enlarged, or fused together, we hardly feel justified in stating that caries was the primary and hyperostosis of the roots the secondary cause, or the result of such a primary cause; for it is possible that the hyperplasia of the roots has been present long before the caries made its appearance. The latter assumption becomes almost a certainty when, upon grinding such teeth for microscopical research, we find either that the caries has not penetrated sufficiently deep to cause inflammation of the pulp, or the dentine is found in a condition which could not be the result of simple 'eburnitis,' but can have been the result only of a malformation at the beginning of its growth in fœtal life.

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* Extract from an article by Frank Abbott. *Dental Cosmos*, 1886.

† L. A. Weil, in an article, "Ueber Cement-hyperplasie," *Oest.-Ung. Vierteljahrschr f. Zahnheilkunde*, III Jahrg., Heft. ii, remarks that the term "hyperostosis" would imply a uniform and flat increase of bone-tissue, whereas "exostosis" means a circumscribed new formation of this tissue. He prefers the term "hyperplasia of cementum" for the designation of all forms of hyperostosis.

"After a careful study of a large number of examples of hyperostosis, I feel entitled to make the statement that the teeth exhibiting it were sound and their pulps alive at the time the bony growth had formed.

"Whenever a tooth becomes deprived of its nourishment from the pulp, I doubt the possibility of an osseous new formation upon the cementum; and, further, should such a new formation have existed previously, its growth has undoubtedly ceased the moment the life of the pulp was gone. Should a dentist extract a sound-looking tooth to relieve excessive pericementitis, or neuralgia suspected to arise from pericementitis, and find the root or roots considerably enlarged, he would hardly be justified in concluding that the pericementitis and neuralgia had caused the growth upon the roots; but, on the contrary, he would naturally conclude that the growth had been the primary feature and the pericementitis and neuralgia secondary features of the disease. If, for instance, to relieve neuralgia, there be removed from one upper jaw a large number of sound-looking teeth, the roots of all of which are found to be considerably enlarged, we conclude that these roots were malformed at the earliest stage of their development. I have in my possession six upper molars, all removed from the same person's mouth, to relieve neuralgia. The roots of all of them are more or less enlarged; three have no decay whatever in their crowns, and the other three are but slightly affected.

"No growth of any tissue is possible without its being first partially reduced to medullary elements. An augmentation of the cementum is impossible without a preceding augmentation of the medullary tissue, which again is caused by increased nutrition, or, as it is generally expressed, an irritation.

"I propose to show that cementum, in a pathological (hyperplastic) condition, is endowed with properties of life the same as in a normal state. Thus it becomes explicable that hyperplastic cementum itself may become the subject of pathological processes, particularly of inflammation. Hyperplastic cementum may, and often does, become partially destroyed by cementitis and transformed into medullary tissue, from which, evidently, an additional new growth of cementum may start.

"Since the beginning of the present century, a good many reliable observers have described and depicted anomalous teeth with hyperostosis in varying degrees of development. Some of these illustrations are striking examples of the excessive growths to which cementum may attain, and still be tolerated by the sufferer. All observers and clinicians, I think, agree that this disease attacks bicuspids and molars only, incisors and cuspids appearing to be exempt; and, again, the teeth of the upper jaw are more frequently affected than those of the lower.

"Facial neuralgia of the most severe and unyielding character is frequently caused by these malformations. At the same time, the symptoms which point to a diagnosis of hyperostosis of the roots are not very marked. When observable at all, they consist of a slight continued uneasiness in the jaw (as sometimes expressed by a patient, 'I can't call it real pain, but I am *constantly* aware that I have a tooth in that locality'). It is akin to pain, with slight soreness of the tooth or teeth upon biting, while excessive pressure upon it in any direction is productive of quite severe and prolonged pain. Eventually the soreness becomes more marked, and the pain constant or intermittent, and finally terminates in possibly an abscess, severe mental derangement, or the removal of the tooth as a cure.

"It is not infrequently the case that a patient suffering from neuralgia applies to a dentist to have a certain tooth extracted for relief, the case being to the dentist so obscure that he takes the patient's word for it, and extracts the tooth; but to his disgust the patient, after a few moments, turns to him and says, 'Why, doctor, that isn't the tooth; the pain is just as bad as it was before you took it out.' This operation is repeated over and over again with the same result, until finally, perhaps, it is the last tooth in the jaw which when taken out reveals the cause of this long suffering, in a root or roots enlarged from hyperostosis. A peculiar feature in these cases is the long-continued and most distressing pain that follows such extractions, relief coming but very slowly.

"As custodian of that portion of the museum of the New York College of Dentistry which pertains to my department, I have come into possession of seventy odd teeth exhibiting hyperostosis of the roots, and this comparatively large number prompts me to try to classify the different varieties as they occur to me. I will here add that about one-third of these teeth are sound or very nearly so. Previous authors have simply described different forms, more or less striking, without observing any system in the arrangement.

Fig. 186.

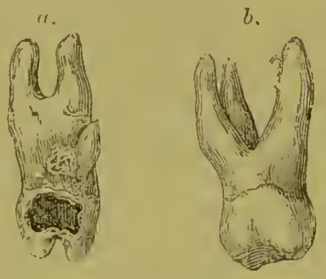
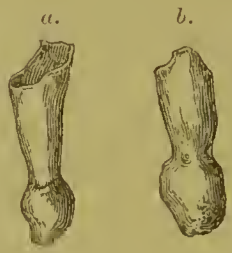


Fig. 187.



"**I. Circumscribed Hyperostosis.**—Under this title are included osteoma and exostosis of the authors, which are characterized by an outgrowth of bone-tissue from the cementum, of a limited size, varying from that recognizable only with the microscope to that of a lentil or a pea. Their surfaces usually present a nodular appearance, and sometimes they are adjacent to newly-formed cancellous structure of bone, evidently caused by osteitis of the socket. I would subdivide this group into:

"A. Osteoma on the body of the root (Fig. 186, *a*, *b*).

"B. Osteoma on the apex of the root (Fig. 187, *a*, *b*).

"Either of these appears mostly upon teeth the crowns of which are more or less destroyed by caries, with probably a long-standing exposed pulp, which plainly indicates that their cause is likely to be accounted for in localized pericementitis from this source. If, however, we bear in mind that the destruction of the life of the pulp prevents or stops the formation of osteoma on the roots, we must come to the conclusion that such tumors had commenced their formation long before the exposure of the pulp, or this must have remained alive for a very long time after its exposure before it died, causing during this long time a slight but constant irritation, transferred to the pericementum.

"As soon as severe pericementitis from an exposed pulp sets in, unless vigorous steps for its relief are taken, the pulp is in a fair way to become lifeless very soon. After its death severe pericementitis and its distressing terminations are too well known to practitioners to need mentioning here. In neither of the latter instances would we expect a bony outgrowth on the roots. It is, in my judgment, only an irritation of the pericementum while the pulp is living that can result in an *increased* cementum.

"In some persons, or conditions of persons, a very superficial decay, more particularly upon the necks of teeth, will produce marked pericementitis and neuralgia. We may infer from this fact that in other persons or conditions (or possibly the same), perhaps under the influence of constitutional disturbances, a local irritation of the pericementum is induced, causing exostosis, long before exposure of the pulp.

"**II. Diffused Hyperostosis with Roots Separated.**—Under this heading a large number of specimens of my collection may be summed up, either of otherwise sound teeth or those decayed or filled. In relation to what I have stated before, I will admit that pericementitis from caries is a cause of hyperostosis only when one root, or two, are involved, others being in a normal condition, and the enlarged root or roots corresponding to the carious cavity either on the neck or crown of the tooth. When all the roots of molars are affected, without the least symptom of disease upon the exposed portion of the tooth in the mouth, I can see no other correct course than to seek for the cause of malformation in the beginning of the formation of cementum,—to wit, during the first year of extra-uterine life. Hyperostosis of this kind invades the roots from the apex to the middle, to two-thirds their length, sometimes even to their necks. The enlargement is either blending with the crown, without a distinct boundary line, or there is a more or less marked bulging of the augmented tissue. The enlarged portion is either in a more or less horizontal line or is fluted, with here and there irregular prolongations toward the crown. In one instance I have seen a small enamel-nodule corresponding exactly to the summit of a marked conical prolongation of the cementum. Sometimes the bulging of the cementum reaches the crown, and may be distinctly seen overlapping the enamel. Such formations are usually either smooth or slightly nodulated. Sometimes they are corroded as if by inflammation; and, again, upon a comparatively smooth mass there may be found bulging forth an irregular nodule of circumscribed osteoma, evidently the result of an excessive formative pericementitis.

"In one of my specimens, a left upper second molar, there is upon the anterior surface of the buccal root a pit two and a half millimeters in diameter and one millimeter in depth, the base of the pit being finely corroded and nodular. On the same surface numerous small nodules are scattered about. On the neck the hyperplastic cementum is one millimeter in thickness, and terminates all around it in a nearly abrupt line. (Fig. 189, *a*.)

FIG. 188.

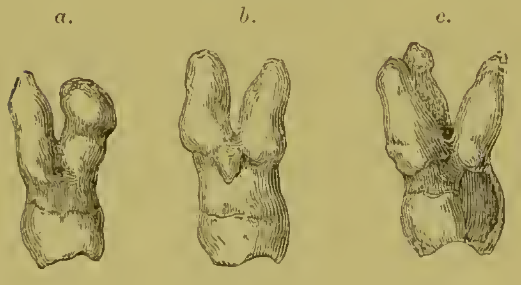
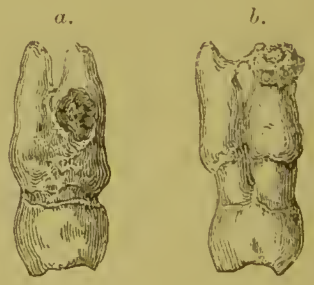


FIG. 189.



"On a right upper second molar the palatal root exhibits at its apex a cauliflower-like excrescence, upon a comparatively smooth osteoma, about one millimeter in thickness, occupying the upper two-thirds of the root. The excrescence sends a delicate conical offshoot to the mass which cements the buccal roots together. The posterior portion of the crown of this tooth has a carious cavity in it the size of a French pea, with the pulp-chamber opened. (Fig. 189, *b*.)

"Roots of this kind look very clumsy and shortened, for the reason that at the place of their union the hyperostosis forms a heavier mass, which has more or less filled the space between them; still, they remain separate to a considerable extent.

"**III. Diffused Hyperostosis with Roots United.**—This group may be subdivided as follows:

"A. Apices free and straight:

"B. Apices free and curved;

"C. All roots united their entire length.

"Teeth of the group A are characterized by an osseous outgrowth of cementum accumulating at the point of junction of the roots,—the roots themselves being either slender and free from osteoma or slightly thickened. An upper wisdom-tooth presenting this anomaly has five roots, three of which are normal at their apices, the fourth being the seat of a diffused hyperostosis encircling it, and the fifth root being rudimentary. All, however, are united into a common mass a short distance from their apices, which mass gradually blends with the enamel. (Fig. 190, *a*.)

FIG. 190.

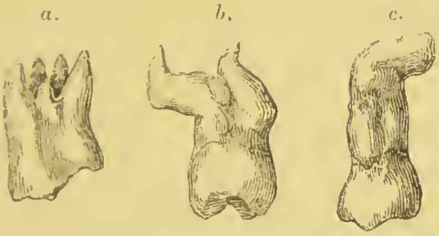
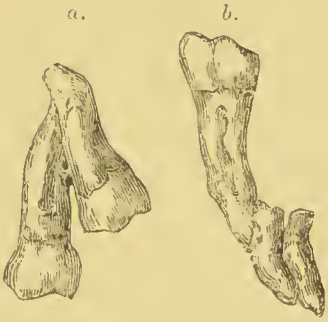


FIG. 191.



"Teeth of the group B exhibit a union of the roots with markedly devious but slender apices. A left upper second molar of my collection shows this evidently rare anomaly. The palatal root is slightly devious, with an apex arising from the main mass of the root at a right angle. The buccal root (there is but one) shows two curvatures, both at right angles. The osteoma is only moderately large, and on the posterior surface, at the point of junction of the roots, there is wedged in a sessile oblong nodule, below which is a shallow furrow, indicating the original point of separation of the two roots. The crown of this tooth is not decayed. (Fig. 190, *b*.)

"Teeth of the group C are rather common. In third molars or wisdom-teeth, of both the upper and lower jaws, a union of the roots is quite generally the normal condition. Osteoma, when found upon such roots, is either a clumsy nodular mass without any sign of a previous separation, or slight furrows may be visible indicative of such separation of the roots. (Fig. 190, *c*.)

"Connected with a lower left wisdom-tooth in my collection there is a history that I will give in abstract, feeling that it may be of interest to some who may hear or read it. This tooth exhibits a diffused osteoma, ridged and nodulated, with a bent apex toward the ramus. It was extracted from the mouth of a lady some years since by my friend, Dr. S. A. Main, of this city, who kindly presented it to me with the following history: For some ten years this lady had suffered most excruciatingly from facial neuralgia. She consulted the best medical talent at home without obtaining the slightest relief. Finally, some three years before the tooth was removed, she went to London, where it was determined by the surgeon who was called to attend her that, in order to afford any relief, it would be necessary to sever the facial nerve upon the side which seemed the most affected, which operation was done,—with, however, only temporary relief. With the hope that the slight cessation of pain would be speedily followed by permanent cure, she went to Paris, anticipating the pleasure of a comfortable tour of the Continent. In a few days the pain returned with renewed energy. In Paris she consulted a surgeon, who decided that the only chance for permanent relief was to have the facial nerve divided upon the other side of the face. The operation was performed with no better results than from the first. Finally she concluded to return to her home in New York, there to spend the few days (as she supposed) which she had to live as comfortably as possible. Shortly after arriving at her home she consulted her dentist (whom, by the way, she had never thought to consult before in reference to her neuralgia), and asked him to look at this tooth, saying at the same time that it often felt quite sore to the touch. (Its antagonist had been taken out many years before.) After examination, she was advised to have it extracted, which was done. Immediately upon its removal the lady realized that the cause of her long-continued, fearfully distressing, and very expensive neuralgia had been found at last, as time proved.

"**IV. Union of Two Teeth through Hyperostosis.**—Of this rare occurrence of the osseous union of teeth I have some eight fine specimens. The subdivision suggesting itself is as follows:

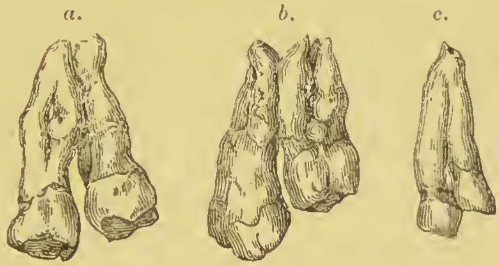
"A. Union of the roots at their apices (Fig. 191, *a*, *b*);

"B. Union of the roots at their middle (Fig. 192, *a*, *b*);

"C. Complete union of the roots (Fig. 192, *c*).

"The first group is characterized by a union of devious roots of neighboring teeth. As both of my specimens show a partial carious destruction of their crowns, the idea may suggest itself that, owing to a destruction of the intervening alveolar wall, and owing to gravitation, the roots became attached to each other through an inflammatory process. At the same time serious objections may be raised against such a view. The main objection is that an inflammation of the pericementum sufficiently intense to destroy the alveolus would be very liable to destroy the pericementum itself, to such a degree as to render quite impossible the secondary new formation of cementum necessary for agglutination of the neighboring roots. Should we assume that the septum was originally absent, the only way of explaining such formations is to suppose that at least one of the germs of the coalesced teeth was malposed at the time of the embryonic arrangement. In this view, it will be observed, the alveolar septum did not form at all, and at the time of development of the roots the mutual pressure was sufficient to cause irritation leading to a new formation. I conclude, therefore, that the carious destruction of the crowns was merely a coincidence rather than a cause (Fig. 191, *a*). The roots of one tooth are mere stumps left after carious destruction of the crown and a portion of the roots. Here the hyperplastic cementum of the stumps is jagged and nodular, plainly indicating that the already formed outgrowth of cementum has been destroyed by cementitis in rather a secondary manner. (Fig. 191, *b*.)

FIG. 192.



"Group B shows a concretion of neighboring roots of molars at the middle, upon one side, and at the apices upon the other. (Fig. 192, *a*.) One of the crowns is slightly affected by caries,

—by no means, however, to such a degree as to account for agglutination of the two teeth, the enlarged cementum of which is mainly smooth. Fig. 192, *b*, represents two molars grown together nearly the entire length of their roots; both teeth being otherwise sound. One of them shows at its neck an 'enamel-drop,' which feature I consider a further proof of embryonal malformation of such teeth. Some exostoses from the sockets are attached to the roots, which fact, in my judgment, proves merely a secondary hyperplastic pericementitis.

"Group C is represented by but one specimen,—that of an upper cuspid united with a neighboring lateral incisor. This seems to be a case which may be considered an exception to the rule,—viz, that only bicuspids and molars are thus affected. In this case the union is perfect the entire length of the roots, and only shallow furrows on the outer and inner surfaces, reaching nearly to a common apex, indicate the previous separation. The apex presents but one large common foramen. At the necks of both teeth there is shallow carious destruction,—not, however, exposing the pulp-chambers. All these features furnish us proof of a fœtal malformation.

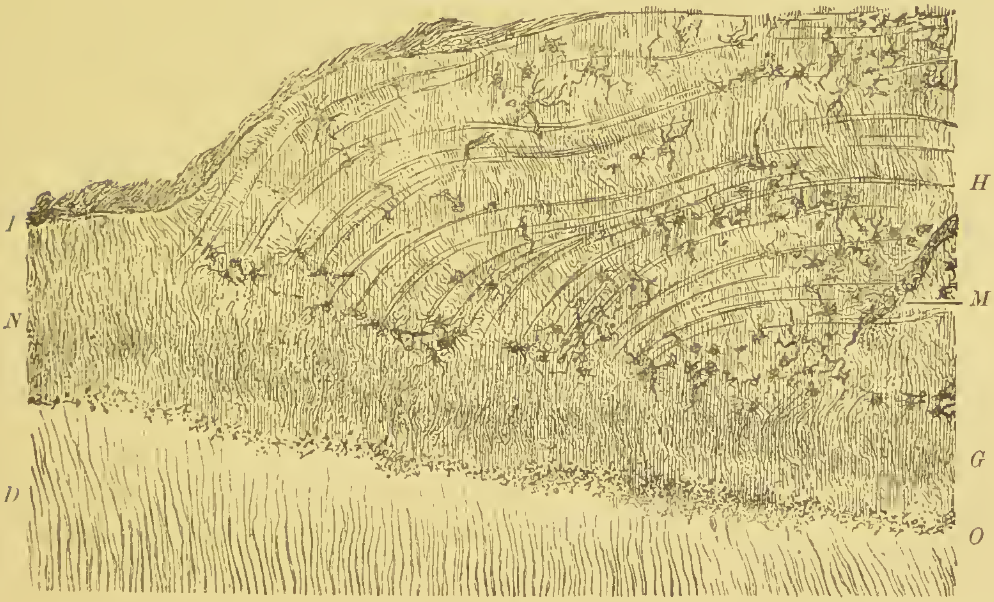
"For the purpose of examining this disease microscopically, I have ground quite a large number of specimens from teeth which at the time of extraction were immediately placed in dilute alcohol, in order to keep them constantly wet, and to preserve their soft parts. During the process of grinding they were also kept under water. All specimens showed in common a number of features which are represented with a comparatively low power in Fig. 193. Those to which I wish to call attention are as follows:

"The dentine in some specimens, perhaps in several localities in the same specimen, was found in a normal condition; and in others it exhibited the so-called interglobular spaces, greatly varying in size and number, indicative of an incomplete calcification.

"In some specimens the dentinal canaliculi of the root were arranged in bundles, between which were found areas scantily provided with canaliculi or altogether destitute of them. In these areas are often seen small interglobular spaces, sometimes in direct union with a few canaliculi.

"The interzonal layer between dentine and cementum invariably exhibited formations known under the name of osteo-dentine, or globular dentine, either as the result of 'eburnitis' or of incomplete calcification. It is a condition kindred to that which characterizes the interglobular spaces of Czermak. Such formations, as a rule, extend into the neck of a tooth,—where, however, they are more scanty than on the roots. A striking feature is their entire absence at the point of junction of the roots. Here the cementum is found in contact with an irregular formation of dentine (vaso-dentine), which will be described farther on. Wedl seems to have been the first to illustrate this formation,—without, however, making an allusion to it in his text.

FIG. 193.



HYPERPLASTIC CEMENTUM SLIGHTLY BULGING TOWARD THE NECK OF THE TOOTH (UPPER BICUSPID). LONGITUDINAL SECTION.

D, dentine; *N*, neck; *P*, pericementum; *O*, globular or osteo-dentine; *G*, granular layer; *H*, hyperplastic cementum irregularly lamellated, with irregularly-distributed cement-corpuscles; *M*, medullary canal. Magnified 150 diameters.

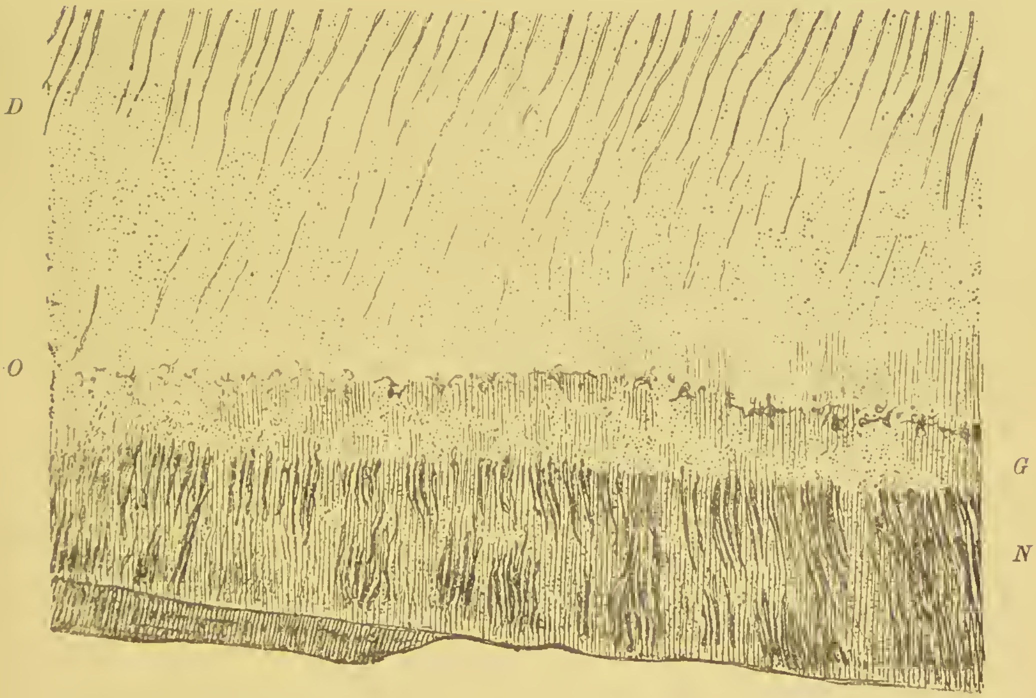
"Next to the layer of osteo-dentine invariably a layer is found which, under lower powers of the microscope, looks coarsely granular, and which in consequence I propose to call the granular layer. It is destitute of cement-corpuscles, and, as a rule, is the only layer comprising the cementum of the neck of the tooth, whenever this gradually slopes from the hyperplastic cementum to the enamel. Next follows the enlarged cementum itself, usually characterized by a large number of irregular lamellæ more or less concentric to the axis of the root. Some areas may be found destitute of lamellæ; others very richly supplied with them. At the border of the cementum toward the crown, where the former often bulges to a considerable extent, the lamellæ are found parallel with the outer periphery of the cementum inosculating with the granular layer at obtuse angles.

"In the lamellated basis-substance are found scattered cement-corpuscles. The most striking features of these corpuscles are as follows: First, they are far more irregularly distributed in the basis-substance than in normal cementum. In some portions of the hyperplastic cementum such corpuscles are comparatively few, whether the lamellæ be plainly marked or not; in other portions they are arranged in groups or clusters apparently without any regularity. Second, the cement-corpuscles, as a rule, are smallest near the granular layer, and largest toward the periphery; at the latter boundary their offshoots are much wider, and more irregular, often piercing the lamellæ rectangularly. No constant relation between lamellæ and cement-corpuscles is to be found. Third, occasionally the cement-corpuscles are to be seen in large numbers clustered together in longitudinal groups. This is probably caused by the previous presence of medullary canals, the tissue of which, at a comparatively late period, has given rise to a large number of cement-corpuscles, and a comparatively small amount of basis-substance between them.

"The hyperplastic cementum is often traversed by medullary canals carrying central blood-vessels. These are most numerous at or near the point of junction of the roots, where, as first described by Tomes, even normal cementum may sometimes contain medullary canals. The vessels of these medullary canals, also first described by Tomes, with whom I am pleased to agree, are in direct connection, and anastomose with the blood-vessels of the pericementum. In one of my specimens the cementum of the neck exhibits peculiar features. Instead of the coarsely-granular layer usually present, and previously alluded to, there is a zone traversed nearly at right angles by bundles of canaliculi, very broad and in no connection whatever with cement-corpuscles. Above this zone lies the ordinary granular zone, bordered toward the dentine by a thin layer of globular dentine; then follows the finely-granular layer of the dentine itself, with very few or no canaliculi, and at last we come to the canaliculated dentine of normal development. (Fig. 194.)

"High amplifications plainly reveal the structure of the interzonal layer between dentine and hyperplastic cementum. The dentine often shows interglobular spaces, which as a rule are filled with granular protoplasm, and serve as the termination of some dentinal canaliculi; especially for their tenants, the fibers of living matter. The interglobular spaces nearest to the cementum sometimes directly inosculate with the interstices between the globular masses of calcified basis-substance, constituting the tissue termed osteo-dentine or globular dentine. The globules themselves vary greatly in size. They usually, however, correspond with the bulk of one or a limited number of medullary corpuscles present before their transformation into basis-substance. The interstices between the globules also vary in size, and send offshoots into the larger globules, subdividing them into incomplete smaller ones. All of them contain granular protoplasm. In the granular zone following the layer of osteo-dentine we sometimes meet with very large and irregular interglobular spaces, apparently in no direct connection with

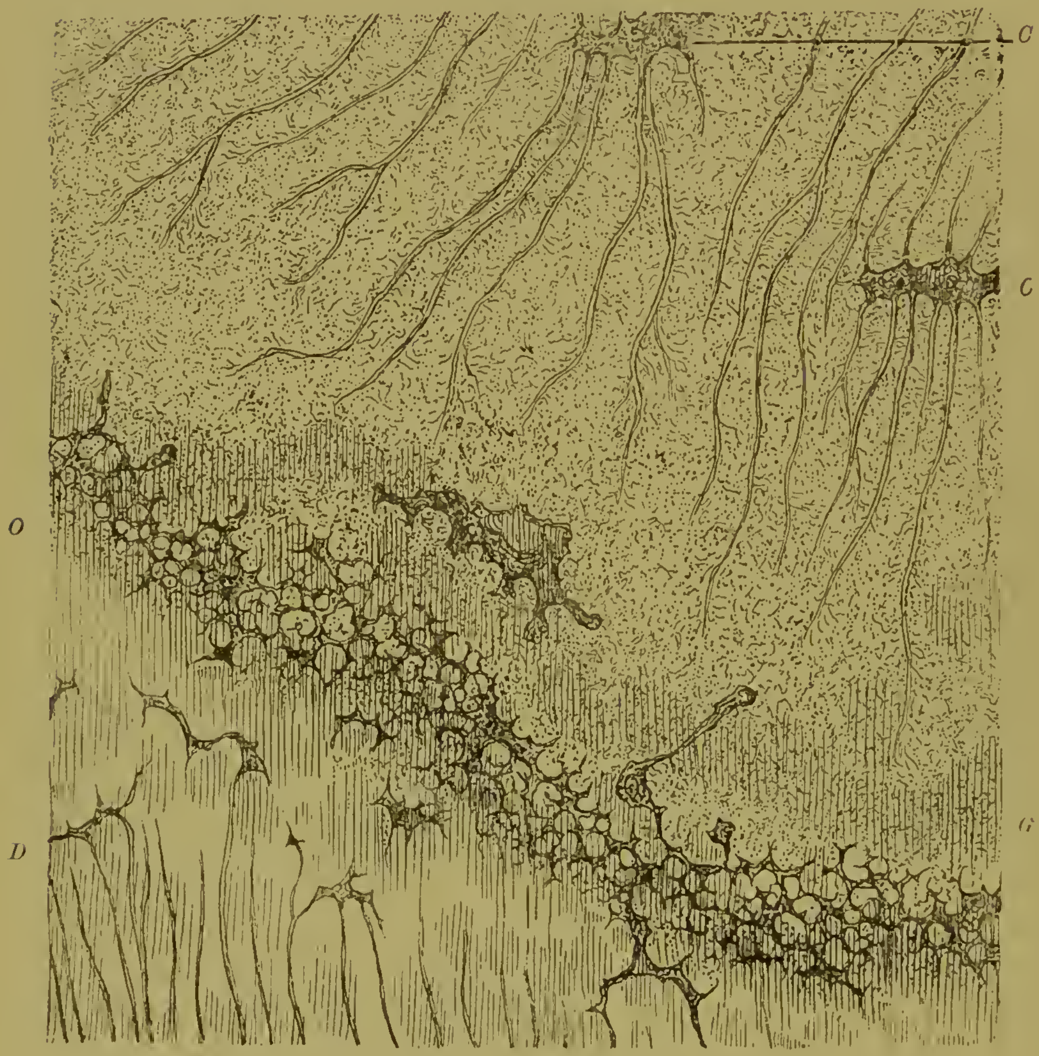
FIG. 194.



HYPERPLASTIC CEMENTUM OF THE NECK OF A MOLAR. LONGITUDINAL SECTION.
N, zone of coarsely-granulated cementum, traversed by bundles of coarse canaliculi: *G*, granular zone, destitute of canaliculi; *O*, zone of globular dentine; *D*, dentine with canaliculi stopped short of the cementum. Magnified 500 diameters.

the offshoots of cement-corpuscles. In several specimens I have seen arising from the cement-corpuscles very long and slightly wavy offshoots, which, owing to their parallel course, bear a close resemblance to dentinal canaliculi. Formations of this kind occur only in those layers of hyperplastic cementum nearest the dentine, and always lose themselves in the granular layer above the osteo-dentine without directly communicating with the dentinal canaliculi proper. (Fig. 195.) The medullary

Fig. 195.



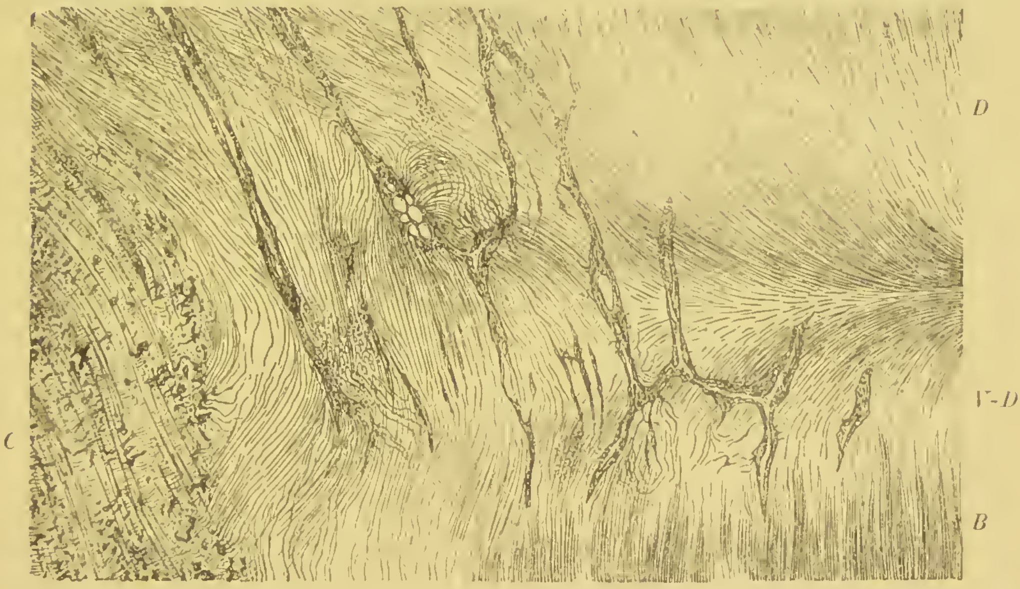
Interzonal Layer between Dentine and Hyperplastic Cementum of a Molar. Longitudinal Section.

D, dentine with small interglobular spaces: *O*, osteo-dentine, above which, in the granular layer *G*, there is a large irregular interglobular space; *C*, *C*, cement-corpuscles with long parallel offshoots. Magnified 600 diameters.

canals traversing the enlarged cementum either contain medullary corpuscles and capillary blood-vessels, or they are filled with highly-refracting granules and globules of lime-salts, as described by Wedl. Should their canals become obliterated, they give rise to groups of cement-corpuscles between a scantily-calcified basis-substance.

"At the point of junction of the enlarged roots in several of my specimens I have met with a peculiar formation of dentine, and as it contains a large number of vascular canals, I propose to term it vaso-dentine. To the naked eye, in the prepared specimen, a high degree of transparency in the vaso-dentine at once distinguishes it from the neighboring opaque portions of normal dentine, and from cementum. Low powers of the microscope reveal in this dentine a varying number of medullary canals, either in a parallel or plexiform arrangement. The canaliculi contain medullary tissue and capillary blood-vessels, one or two in each canal. Sometimes glistening granules of lime-salts are found, more especially in dilated portions of the

FIG. 196.



VASO-DENTINE FROM THE JUNCTION OF THE ENLARGED ROOTS OF AN UPPER MOLAR. LONGITUDINAL SECTION.

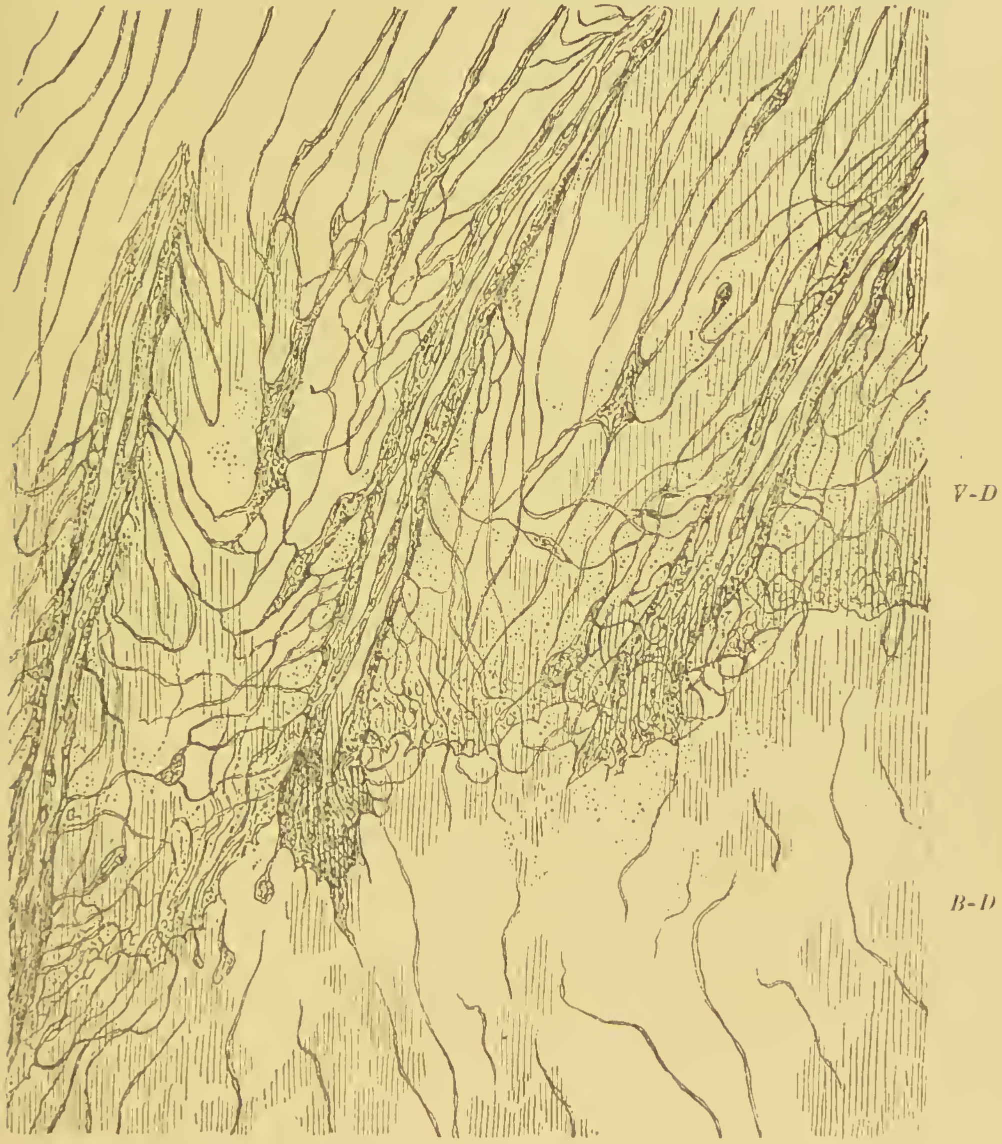
D, primary dentine; *V-D*, vaso-dentine traversed by medullary canals in a plexiform arrangement,—the canals contain either blood-vessels or glistening depositions of lime-salts; *B*, basis-substance of dentine scantily provided with extremely delicate canaliculi, and in some places fan- and fountain-shaped figures of dentinal canaliculi discernible; *C*, hyperplastic cementum lamellated, and containing a medullary canal. Magnified 50 diameters.

canals. Offshoots of such canals may inosculate with very narrow canals containing granular protoplasm only. The surrounding basis-substance is scantily supplied with extremely fine canaliculi, running, without any apparent regularity, in fan-shaped groups, or parallel with the medullary canals, or in the shape of a fountain, encircling the canals in the most beautiful and striking figures. Some portions of the basis-substance may look granular and devoid of canaliculi; others (and these formed a vast majority) are apparently homogeneous, and scantily supplied with extremely minute canaliculi. The cementum is directly on the border of the vaso-dentine, without any intervening layer of granular dentine, and the cement-corpuscles nearest to the dentine are in direct connection with the dentinal canaliculi themselves. (Fig. 196.) Higher powers of the microscope brought to bear upon the vaso-dentine plainly show the medullary contents of the medullary canals, in which may also be seen one or two capillary blood-vessels. Both the canals and blood-vessels produce loops, as is indicated by their abrupt terminations in vertical sections, and are unquestionably in communication with the blood-vessels of the pericementum (Tomes). A peculiar feature of the vaso-dentine is that portions freely supplied with vascular canals contain a considerably larger number of dentinal canaliculi than those devoid of vascular canals.

"The canaliculi in the neighborhood of the vascular canals are very irregular in their course, as before stated, and often loop-shaped, starting from and inosculating with the same vascular canal. Again, we find them starting from club-, pear-, spindle-, and irregular-shaped spaces, containing medullary corpuscles, or granular protoplasm, but no blood-vessels. (Fig. 197.) I would mention that in all my specimens, as an additional feature of hyperostosis of the roots, the pulp-chamber and often the canals appear considerably narrowed by heavy formations of secondary dentine. Besides, the pulp-tissue was found to contain formations of secondary dentine known as pulp-stones, or to be crowded with globular calcareous depositions of no definite structure. In the majority of the teeth the enamel also was imperfectly formed, it generally presenting a highly-pigmented and imperfectly-calcified condition, with enamel-rods very irregular and curly.

"A striking feature in all microscopical specimens of hyperplastic cementum is the great number and large size of the offshoots of the cement-corpuscles, the canaliculi, previously so called. The reason for this seems to be that both the corpuscles

FIG. 197.



VASO-DENTINE FROM THE POINT OF JUNCTION OF THE ENLARGED ROOT OF AN UPPER BICUSPID. LONGITUDINAL SECTION.

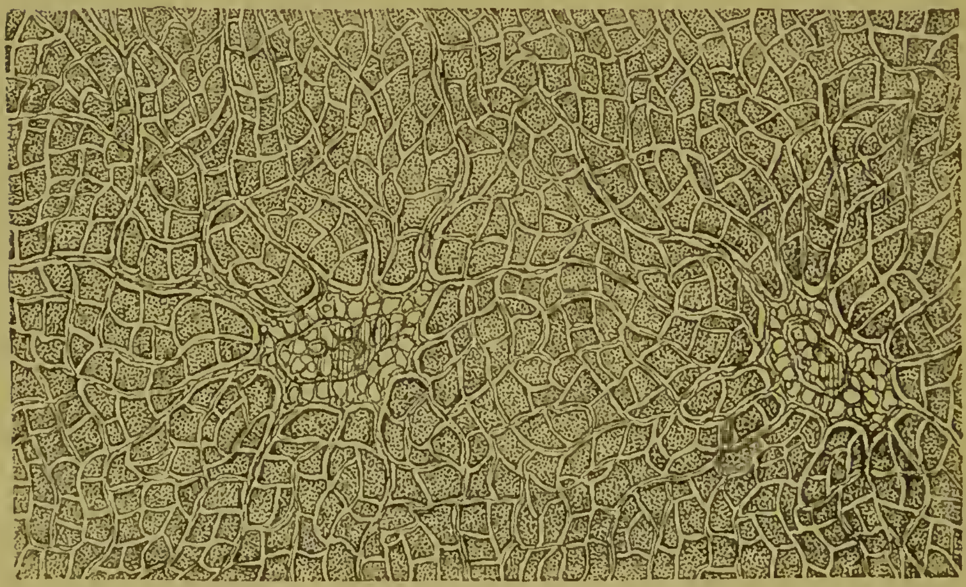
V-D, a portion of vaso-dentine with three parallel vascular canals, and very irregular, often looped, canaliculi, some starting from the vascular canals and others from smaller medullary spaces; *B-D*, dentine of great transparency, with scanty canaliculi. The boundary line between the two portions is abrupt, with numerous bay-like excavations. Magnified 500 diameters.

(lacunæ) and their coarser offshoots (canaliculi) are filled with air, or dirt from the grinding, which causes them to look black.

If, however, we place a carefully but not completely decalcified portion of this tissue, mounted in glycerin, under a very high power, we are struck with its beautiful and graceful appearance. It is identical in structure with that of normal cementum. The basis-substance forms cavities that contain nucleated protoplasmic bodies, the cement-corpuscles proper, of a markedly reticulated structure.

"Between the periphery of the cement-corpuscles and that of the lacuna there is a narrow light rim, obviously corresponding to a space that serves for the circulation of the nutritive liquids. The lacuna at its periphery is interrupted by numerous offshoots, wider and more irregular than those of normal cementum. These canaliculi form an extremely delicate reticulum throughout the basis-substance, interconnecting the neighboring lacunæ (indeed, all lacunæ) of the cementum.

Fig. 198.



Hyperplastic Cementum of an Upper Molar. Cross Section.
Magnified 1500 diameters.

"Starting from the periphery of the cement-corpuscles, conical offshoots run into the canaliculi; the broader, of course, the wider the canaliculus. The coarsest offshoots still exhibit a reticular structure; whereas the finest are merely beaded threads occupying the middle of the canaliculi. Thus it will be seen that all canaliculi hold filaments of living matter in a cobweb arrangement, and thus it becomes plain that hyperplastic as well as normal cementum is a living tissue throughout. The reticular structure of the living matter in the corpuscle itself is plainly visible. The inert basis-substance, infiltrated at the same time with lime-salts, is located in the meshes of the reticulum of the canaliculi, and between the basis-substance and filaments of living matter a slow circulation is going on, the liquid carrying nourishment and taking away the effete material. (Fig. 198.) Thus it is that pathological changes of a pathological tissue become intelligible, and cementitis of hyperplastic cementum, as described and illustrated by Wedl, under the term 'perforating resorption,' is understood.

"Macroscopically I have already described this condition. Under the microscope it is characterized by the presence of cavities filled with medullary corpuscles, or multinuclear protoplasmic masses, and bounded toward the unchanged cementum with numerous bay-like excavations. The destruction may involve superficial portions of the tumor only, or the entire mass down to the dentine. As there is little tendency to suppurative pericementitis, the termination of the inflammatory process undoubtedly results often in a re-formation of cementum, the same as takes place during the process of absorption of the roots of temporary teeth. Under these circumstances the bay-like excavations are refilled with bone-tissue, and the bays are recognizable by sharply-defined lines corresponding to the territories of the cement-corpuscles. Some of my specimens exhibit bay-like excavations directly separating the cementum from the dentine, and the bays filled with bone-tissue crowded with cement-corpuscles. In other specimens certain portions of the hyperplastic cementum show distinct circular, semicircular, or crescentic lines corresponding to the territory of one or more cement-corpuscles."

CHAPTER XXXI.

INFLAMMATION.*

"It is the gift of genius to foresee discoveries even for centuries. Such a genius was John Hunter, of London, who toward the end of the last century, merely upon the ground of speculation and ratiocination, made the assertion that inflammation is none other than a return of the tissues to embryonic condition. And our present knowledge of the process of inflammation and suppuration is a strong proof, supported by careful researches of good pathologists of Germany and England, that Hunter's theory was the correct one.

"Since microscopy became a science (a period covered by half a century) the views concerning the intimate nature of the inflammatory process have been greatly at variance. These views largely depend upon the general ground taken by pathologists in reference to the pathological processes at large. We have three marked phases in the development of pathology within the last fifty years. The first is the standard of humoral pathology promulgated by the late C. Rokitansky, of Vienna. The second is the phase of cellular pathology established mainly by R. Virchow, of Berlin. The third phase, still in vogue with many pathologists, is the doctrine of emigration of colorless blood-corpuscles or leucocytes, as propounded by the late I. Cohnheim, of Leipsic.

"During the past five years bacteriology has held sway of the minds of the majority of the pathologists, proving what was just stated. To-day no one will be rash enough to neglect the influence of bacteria in producing suppuration. And have we not learned through excellent observers that it is not the micro-organisms themselves, but rather their chemical products, the ptomaines, that play the important rôle in the causation of suppuration and possibly of inflammation? I here allude to the researches of Leber, of Göttingen, who maintains that it is a ptomaine, called by him *phlogestein*, that stands in causal relation to inflammation.

"The task I have undertaken is to review the theories held in the last fifty years, closing the historical remarks with a description of what I consider to be the truth to-day. The review of such a history is instructive in many respects. It teaches us that no one, be he of the most gifted talent, is able to emancipate himself from preconceived ideas and accepted notions. It furthermore teaches us that we are the subjects of general theories extant at the time in which we make our investigations. It teaches the great lesson of modesty and humility. If a man of my age must confess in the seventh decade of his career that he has been misled in his younger days by books and teachers and must try hard to unlearn what he thought he knew before, it is certainly testimony of human frailty, and goes far to prove that we are obliged to consider the truth to be truth only *pro tempore*,—viz, so long as we do not know better.

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* Much of this chapter is based upon the investigations of Wm. H. Atkinson: "The Origin of Pus," *Journal of the American Medical Association*, 1889.

"In the fifth decade of our century humoral pathology was thought to hold the full truth in the explanation of inflammation. The older of us will remember what facts the humoral pathology was based upon. The web of the foot of a living frog was expanded over a cork ring and the web touched with an irritating agent, such as a droplet of ammonia, an acid, or with a pointed, red-hot iron, and the subsequent changes observed under the microscope with the comparatively low powers at the disposal of investigators of the time. They saw around the irritated portion of the web an undulation of the currents of the blood within the vessels, shortly afterward a slacking of the current, and still later a standstill of the stream. The last phenomenon they called 'stasis,' and this stasis was thought to be the essential feature of the inflammatory process. Many and animated controversies arose over the question, What is the stasis due to? Most observers agreed that a paralysis of the capillary blood-vessels, after a few preceding contractions, was to be considered the cause of stagnation. At the same time an inundation was seen to take place in the affected tissues with a liquid which of necessity must have come from the general blood-column, and was termed 'exudate.' According to the nature of the exudate different varieties of inflammation were set up, such as the 'serous,' the 'fibrinous,' the 'albuminous,' and should blood have been admixed with the exudate, the 'hæmorrhagic.' Corpuscular elements seen in the affected territories and apparently suspended in the *exudate* were thought to have originated from the exudate itself; therefore the pus-corpuscles would have originated from the exudate, the latter from the blood, hence the definition of pus, 'dead blood.' No stress was laid upon the structural changes of the affected tissue itself, except so far as the exudate saturating this tissue was concerned. The ultimate cause of inflammation and suppuration was sought in chemical mixtures of the blood, termed dyscrasia, which means bad mixture of the blood. If a person became affected with lobar pneumonia the cause surely was surplus of fibrin in the blood, or fibrinous dyscrasia. If a person produced a number of abscesses in his organism, the cause was denominated purulent dyscrasia. All diseases were, in this dyscrasic view, essentially diseases of the blood. The blood in its mixture caused the diseases simply by being overloaded with obnoxious or effete material.

"The man who dug the grave of humoral pathology was Virchow, in the beginning of the sixth decade of the present century. To him the phenomena of alterations in the circulation of the blood were of secondary importance. The stasis he would not admit as a cardinal symptom of inflammation, for it would mean rather death of the tissue, gangrene or necrosis. The exudate also played but a secondary rôle, serving only as a pabulum to the living corpuscular elements of the tissues, the so-called *cells*. Inflammation was, in Virchow's opinion, a structural change of the affected tissue, mainly morphological changes of the cells themselves. The cells being the seats of life, would attract and, as it were, imbibe the exudate, swell up, divide and come to a state of proliferation, in which a number of cells would arise from an original single cell, and the large number of newly-formed cells would replace the intercellular substance lost by liquefaction. A formation of cells out of a previous liquid or semi-solid exudate was declared to be impossible, since all newly formed cells must have arisen from pre-existing cells. Dyscrasias were done away with. The main causes of inflammation were peculiarities of the tissue itself, and a certain weakness of the tissue was proposed to explain the predisposition to inflammatory processes. The word suggested for this supposed local weakness of the tissue was 'diathesis.' If a man suffered from articular rheumatism, the cause was said to be 'rheumatic diathesis.' Tuberculous persons were predisposed to cheesy degeneration simply because they were afflicted with *tuberculous* diathesis. In the same sense hemorrhagic and purulent diatheses were spoken of. The pus-corpuscles were without exception an offspring of the previous cells of the tissue, and in this sense pus was considered dead tissue. Cellular pathology has made a very strong impression on the minds of observers. Even the stalwart humoral pathologist Rokitansky yielded to the novel views, and accepted the doctrine that no cell will grow in an exudate unless previous cells be there. Cellular pathology even in our day governs the minds of most pathologists over the civilized world. Prolifera-

FIG. 199.

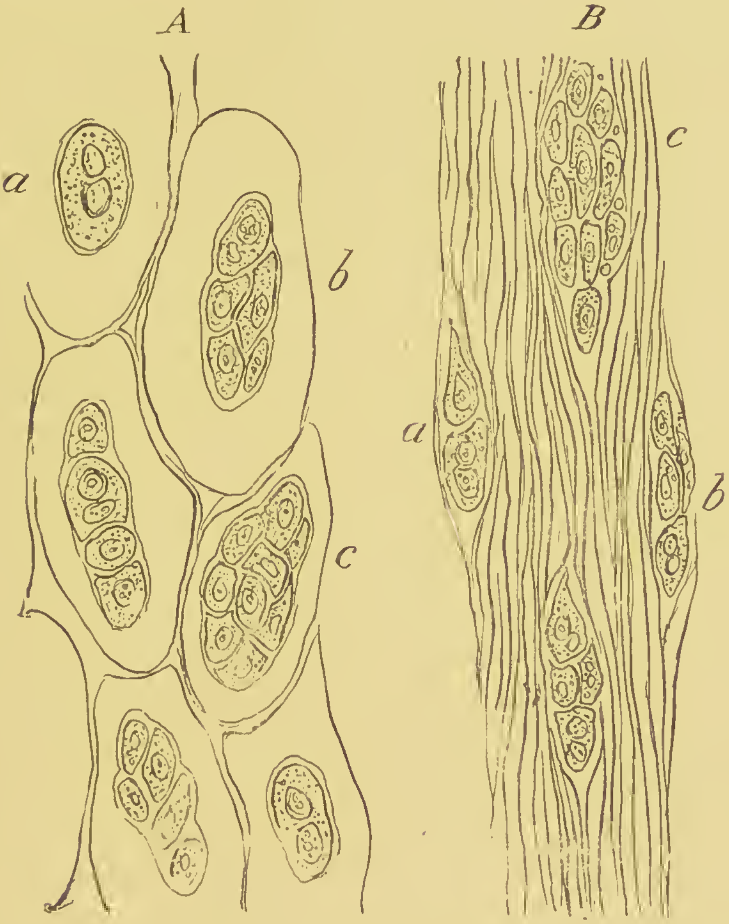

DIAGRAM OF THE INFLAMMATORY CHANGES OF CONNECTIVE TISSUE. CELL-PROLIFERATION ACCORDING TO R. VIRCHOW (1852).

A, *inflammatory changes of reticular cartilage.*—*a*, division of the nucleus of the cartilage-cell; *b*, division of the cell into a number of cells; *c*, proliferation of cells,—the intercellular substance gradually liquefied. **B**, *inflammatory changes of fibrous connective tissue.*—*a*, division of the connective-tissue cell; *b*, further advanced division of the connective-tissue cell; *c*, high degree of division and proliferation,—the fibrous intercellular substance gradually liquefied.

tion of the cells accounts for all tissue-changes, either newly formative, the so-called hyperplasia, or destructive, that is, suppuration. Proliferated cells being present in either of these instances, cellular pathology is at a loss to explain why a certain tissue, owing to proliferation of its cells, becomes augmented and hyperplastic in one instance and is destroyed by suppuration in the other. Still, in spite of all weaknesses of this doctrine, we must consider it an advance in comparison with the teachings of humoral pathology. The cell being supposed to be the only center of life, inflammation and suppuration were for the first time considered as the phenomena of life, and the idea began to dawn in the minds of pathologists that inflammation and suppuration were morbid processes occurring in tissue-elements endowed with life, the so-called cells. (See Fig. 199.)

"The third period arose in the middle of the seventh decade of our century, when Cohnheim observed a migration of colorless blood-corpuscles through the walls of the capillaries and small veins of an exposed and expanded mesentery of a frog. Several years before S. Stricker, in Vienna, observed the red corpuscles pass through the walls of the capillaries of the nictitant membranes of the live frog, so-called diapedesis. Even in 1848 the emigration of leucocytes had been seen in England by Walker and Wallace. The facility with which the emigration of leucocytes could be seen under the microscope has induced many German pathologists to accept the view of Cohnheim, that inflammation and suppuration are but an emigration of colorless blood-corpuscles. These accumulating in a tissue whose cells would remain inert and whose intercellular substance would become liquefied and destroyed, furnish a representation of both inflammation and suppuration. With this view there was nothing alive in the body but the leucocytes. At first Cohnheim denied the participation of the so-called stable cells in the process of inflammation, but later he admitted that in reparative inflammation the tissue-cells do proliferate and furnish their share for the benefit of newly-forming tissue, exactly in the sense of cellular pathology. That pus-corpuscles should be emigrated colorless blood-corpuscles was intelligible, as isolated corpuscles were nearly identical in appearance. How new tissue could form from leucocytes remained a deeply-shrouded mystery, as no observation has as yet proved that through coalescence of leucocytes new protoplasmic masses and new tissues can arise. The observation of Ziegler, of Tübingen, that multinuclear bodies, so-called giant-cells, are visible between thin glass plates introduced under the skin of an animal, lacks the proof that such giant-cells arose by coalescence of leucocytes. On the contrary, later observations made especially upon deciduous, replanted, and implanted teeth, go far in proving the giant-cells to be an offspring of the myxomatous granulation-tissue, sprouting in all directions, filling the bay-like excavations on the deciduous and other teeth and carrying blood-vessels into places where there had been none before, leading to the vascularization of a new tissue,—seen, for instance, in sponge-grafting.

"S. Stricker immediately sought to overthrow the teachings of Cohnheim. In his investigations he used almost exclusively the cornea (chiefly of frogs, cats, and rabbits), in which he induced inflammation by introducing a thread. The changes were faithfully watched up to the formation of abscess around the foreign body. The observations enabled him to prove the established views of cellular pathology to be correct,—namely, that these so-called cells divide and subdivide, but also that the coarser offshoots of the cornea-corpuscles split up, and by division produce new corpuscular elements. Stricker also held, up to 1874 (Ashhurst's International Surgical Cyclopædia), that pus-corpuscles were products of proliferation of the cornea-corpuscles and their coarser offshoots. Unfortunately, he called all the products of cells originating from proliferation of previous cells pus-corpuscles. Indeed, it was impossible to discriminate between inflammatory corpuscles and pus-corpuscles, since all of these appeared isolated under the microscope. Clinically it is well established that every inflammation does not terminate in suppuration. Particularly do we know of a termination which instead of causing destruction of an affected tissue, as suppuration does, brings about a new formation, an increase of the bulk of the tissue,—the so-called hyperplasia. How shall we explain such marked differences by the theory of cellular pathology, which claims that all corpuscular elements are isolated from the start? However, since 1880 Stricker has been a convert to the views of C. Heitzmann, established in 1873, which doctrine I advocate, having studied specimens, illustrative of inflammation and suppuration, under the microscope in that investigator's laboratory.

"Recent researches of botanists go far to prove that even in the plants there exist no individual cells, but that the intervening cement-substance, or cellulose, is traversed by minute bridges of living matter, rendering the plant an individual from the tips of the leaves to the sporacles of the rootlets. Recent observers in animal and vegetable microscopy have drawn attention to the fact that by means of certain reagents the nucleus will be split up into loop-like threads, a process which they consider precedes the division of the nucleus and indirect division of the protoplasm. This process is termed karyokinesis, or mitosis,—'fibrillation,' 'thread-making.' This observation is had only with certain reagents, and is not visible in the fresh specimen or in one preserved in a chromic-acid solution. Suspicion naturally arises that the loop-like figures of the nucleus are artificially produced, and thereby their connections are rendered invisible. The threads forming the loops are called 'chromatin,' because they are readily stained by aniline dyes, whereas the intervening substance and the protoplasm itself stain but little, and therefore are 'achromatin.' Facts rendered conspicuous by staining applications only are of doubtful correctness. The fact that there are threads and loops in the star-point form arrangement in the nucleus rather proves the latter to be made up largely of living matter, which is known to change shape any moment. Coarse formations of living matter readily stain with aniline dyes, whereas delicate formations of the same substance will not stain. The connections between the loops of the nucleus and the surrounding radiating reticulum of the protoplasm are plainly visible in fresh specimens, and also those preserved in liquids which we know will not alter the structure of protoplasm, such as a solution of chromic acid of one-tenth to one-half of one per cent. Alcohol as a preserving fluid is far inferior, owing to the shrinkage it effects.

"Whenever irritation is brought to bear upon a living tissue reaction will follow, and this is an inflammatory process. The first step is liquefaction of the basis- or cement-substance, probably induced by the presence of an acid, likely lactic. Thus the living matter previously concealed (held) in the basis- or cement-substance becomes liberated, and the protoplasmic form of the basis-substance reappears. This condition has been observed directly by S. Stricker in the cornea of frogs, as before stated. He saw the basis-substance in motion, changing the configuration of its living matter, under the microscope, much like clouds changing on the face of the sky. Next the protoplasm furnishing the substratum of previous basis-substance becomes split up into small bodies, known as medullary, or embryonal, or inflammatory corpuscles. Any portion of living matter of such indifferent bodies may grow to the size of a nucleus, owing to the presence of an excess of pabulum beyond the physiological requirements of these bodies, an excess essential to the inflammation. Not only the original 'cells,' but the intervening basis-substance, will participate in the formation of new elements or inflammatory corpuscles. Here is the distinguishing feature between modern and antique pathological views, for according to the latter only the 'cells' themselves were considered active and capable of proliferation."

At the beginning of 1892,* P. Grawitz, professor of morbid anatomy at the University of Greifswald, Germany, published an article,† followed by several others, in which he claimed to have discovered that in the process of inflammation not only the cells of the connective tissue proliferate, but the basis-substance likewise furnishes a large number of cells, which he termed slumbering cells. Grawitz believes that the basis-substance has been developed from cells which remained slumbering until again brought to view by an irritative process, such as inflammation. E. O. Shakespeare, of Philadelphia, in 1882, had previously written of slumbering cells, which he noticed buried in the basis-substance of the cornea. Quite recently Professor C. Weigert, of Frankfurt, Germany, bitterly attacked Grawitz,‡ calling his discovery "intercellular pathology," in contradistinction to Virchow's cellular pathology. He criticised Grawitz that the latter had ignored the researches into inflammation during the last twenty years, and quoted Stricker as having first discovered that during the process of inflammation the basis-substance likewise produces cells. Weigert, however, still adheres to Cohnheim's emigration theory, and has never admitted that the connective-tissue cells do proliferate. He tries to explain the images of proliferation by stating that the colorless blood-corpuscles, or leucocytes, creep into the tissue-cells, thus producing the appearance of proliferation.

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* This and the following paragraph, with the illustrations, are reprinted from "The Doctrine of Inflammation," by C. F. W. Bödecker. *International Dental Journal*, 1893.

† *Virchow's Archiv. Berliner Wochenschrift.*

‡ *Deutsche Med Wochenschrift*, 1892.

Fig. 200.

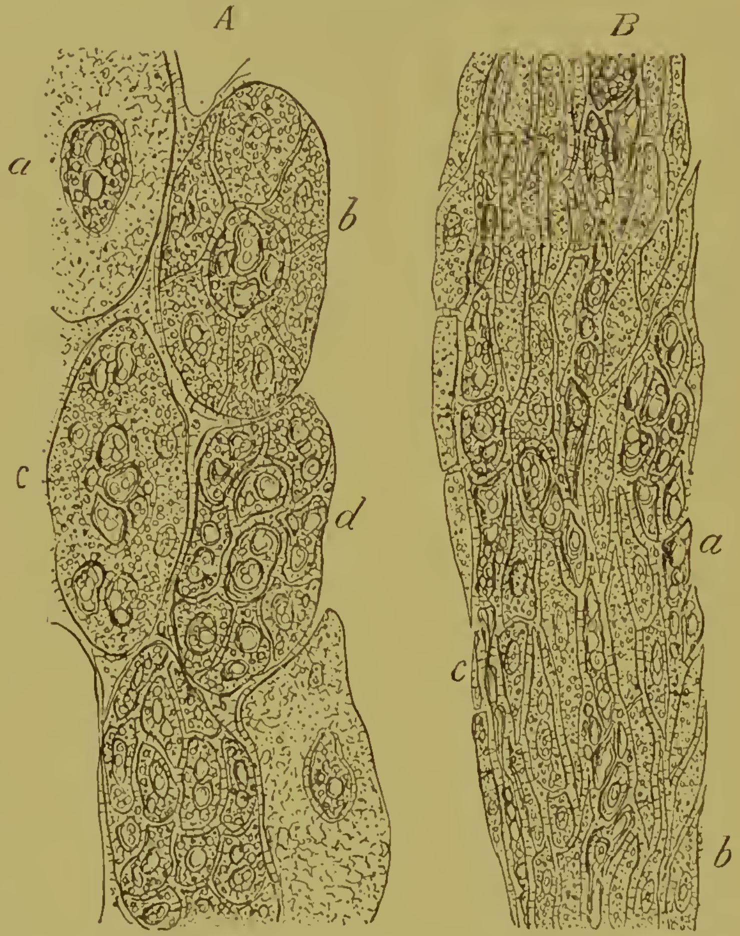

Diagram of the Inflammatory Changes of Connective Tissue. Reduction of Basis-Substance to Protoplasm according to C. Heitzmann (1873).

A, *inflammatory changes of reticular cartilage.*—*a*, increase of the living matter in the central protoplasmic body, beginning reappearance of living matter in the basis-substance; *b*, territory composed of embryonal corpuscles, after liquefaction of basis-substance; *c*, reappearance of nuclei in the basis substance; *d*, territory broken up to inflammatory corpuscles. **B**, *inflammatory changes of fibrous connective tissue.*—*a*, original protoplasmic tracts broken up to inflammatory corpuscles; *b*, fibrous basis-substance transformed to nucleated protoplasmic bodies,—the "slumbering cells" of P. Grawitz; *c*, inflammatory infiltration, all the elements interconnected by threads of living matter.

Grawitz admits that he is ignorant of these researches. Weigert, on the contrary, confesses the knowledge of Stricker's publications, but purposely ignores them, because they are adverse to the doctrine of the cellular pathology.

It is remarkable that the German pathologists have arrived at discoveries which were made twenty years ago, not by Stricker, as stated, but by Carl Heitzmann, of New York, at that time in Vienna. Stricker himself publicly announced in 1880 that he became convinced of the correctness of the views of Heitzmann only after six years of hard work. He unquestionably was the first in Europe who acknowledged (twelve years ago) the accuracy of Heitzmann's theory. The discovery, however, is not his.

"The sum-total of the newly-formed inflammatory corpuscles is known under the term inflammatory infiltration, which means that a certain amount of a tissue, be it connective, muscular, or nerve tissue, is replaced by and transformed into newly-appearing protoplasmic bodies in the stage of indifference,—that is, being purely protoplasmic bodies without any distinctive tissue character either as to origin or destiny. So long as the inflammatory corpuscles remain in continuity by their delicate offshoots they represent a tissue, though in a condition of indifference, or an embryonal state. Such a tissue by new formation of a basis-substance will either return to the previous normal state, terminating the inflammatory condition in 'resolution,' or, being considerably augmented itself, will produce a tissue much greater in bulk than the one originally inflamed, and we will have hyperplasia.

"*Hyperplasia*, therefore, appears when, in consequence of the increase of the living matter after the new formation of basis-substance, a certain bulk of tissue is formed in excess of its previous normal quantity. In this condition the cells as well as the basis-substance remain interconnected the same as in the production of a normal tissue.

"In neither instance will the inflamed tissue cease even for a moment to be tissue. The tissue which is the bearer of the blood- and lymph-vessels is the connective tissue, and here is the starting-point of inflammation in almost every instance. This we understand from the fact of the rather low status and activity of the connective tissue. We look for the greatest reaction on irritation at the sources of nutrition, obviously the blood-vessels. Muscle, nerve, and epithelial tissue react in rather a secondary manner on inflammation of connective tissue.

"Virchow proposed the name 'parenchymatous inflammation' for the designation of an inflammatory process which he thought to be primary in epithelial structures. This term may be retained if restricted always to a secondary manifestation upon the primary inflammation of the 'interstitial' connective tissue. A gland, for instance, is a compound organ composed of parenchyma according to Virchow, which is the epithelial glandular tissue. This is surrounded with and accompanied by connective tissue bearing many blood-vessels. It is impossible that the glandular tissue could be the primary seat of the inflammatory process. This process will be present in the connective tissue first, and more or less rapidly invade the glandular epithelial tissue.

"If the connections of the inflammatory corpuscles be severed, we shall have a certain number of isolated medullary or embryonal corpuscles suspended in an albuminous liquid, and this we call *pus*. Pus is therefore the resultant of destroyed tissue, but quite unfitted for the production of any form of tissue. How much the emigrated blood-corpuscles contribute to the formation of pus may not yet be positively stated. However, we do know positively that upon the approach of suppuration in a certain tissue its blood-vessels are destroyed without exception in the territory involved. The blood-vessels, by outgrowth of their endothelia, become at first solidified and afterward split up into medullary and pus-corpuscles, the same as all the other elemental constituents. Even the smooth muscles of an artery will partake of this pus-forming process. The number of migrated leucocytes cannot be great, considering the loss of the vessels which have supplied them. Pus is destroyed tissue, first originating in a closed cavity bearing the name of 'abscess'; or, secondly, coming from the walls of physiologically shut cavities, termed 'empyema'; or, thirdly, springing from exposed tissue surfaces, viz, such as granulating surfaces of wounds, termed 'pyorrhœa.' In the two latter instances, namely, empyema and pyorrhœa, the emigration of colorless blood-corpuscles plays, perhaps, a more important rôle than in the case of 'abscess.' In granulating surfaces of wounds, especially, the source of the pus-corpuscles may be sought mainly in the capillaries, which abound in the myxomatous granulation tissue, producing loops therein, upon the grouping of which depends the raspberry look of the so-called 'proud flesh.'* Around an abscess a dense layer of fibrous connective tissue is formed very soon,—beautifully displayed in alveolar abscess at the apices of diseased roots of teeth. This newly-formed layer represents the productive activity of inflammation, being hyperplastic, fibrous connective tissue, more or less well supplied with blood-vessels. Old pathologists termed this layer 'membrana pyogena,' which signifies that the membrane itself produces the pus. This view was abandoned long since, and to-day the membrana pyogena is known to be a secondary formation in the appearance of an abscess, as it were, a protective wall to the healthy tissues. After the evacuation of the pus from an abscess or an empyema, either by spontaneous rupture of the covering layer toward the surface, or artificially by knife or caustic, the membrana pyogena changes its character and becomes the seat of an acute inflammation, which leads to the formation of a freely-vascularized myxomatous tissue. This is what is called 'proud flesh,' or granulation-tissue. In all instances of loss of tissue by suppuration, the final result is the formation of a scar. This consists of a dense fibrous connective tissue whose bundles freely interlace, and which is, as a rule, scantily supplied with blood-vessels. It is an outcome of myxomatous granulation-tissue, and is covered with epithelium whenever the pus has been discharged through the skin or a mucous membrane, which themselves appear to be covered in a normal condition with an epithelial layer.

"Pus, therefore, is a tissue disintegrated and broken up into indifferent or medullary corpuscles which are suspended in a liquid more or less rich in albumin. The pus-corpuscles remain alive as long as the liquid surrounding them is sufficient for the support of their nutrition. Even fatty degeneration of the pus-corpuscles, as seen in chronic abscesses, will not altogether deprive them of their vital phenomena. Such corpuscles, if transferred upon a slide, remain amœboid, and they die only by exposure to a low temperature, or after the addition of chemical reagents, or within the body by being deprived of their nourishing liquid. The last condition is noticed in cheesy degeneration of the pus so often met with in tuberculosis.

"A question now arises: What is the cause of the formation of pus? Ever since the famous experiments of Cohnheim and Councilman, who introduced vials filled with croton oil under the skin of rabbits, with antiseptic precautions, and after healing was complete cracked the vials, subcutaneously, thus producing an abscess, this is a much-mooted question. A host of experimenters, who have repeated these trials, have taken views pro and con on the question. I consider the experiments of P. Grawitz and W. deBary, published in Virchow's *Archives*, 1887, the most valuable testimony toward settling the question. They found that the subcutaneous injection of concentrated solution of chloride of sodium in rabbits and dogs was followed by œdema, a swelling of the fascia, but no suppuration. It makes no difference whether the solution contains a large number of staphylococci. Staphylococcus, with its three varieties, the Staphylococcus pyogenes aureus, albus, and citreus, first discovered by Rosenbach, was thought to be essential to the production of pus. And even H. Knapp, of New York, maintained that a small quantity of croton oil mixed with olive oil will not produce suppuration if introduced into the anterior chamber of the eye of the rabbit, whereas the same mixture if contaminated with pure culture of Staphylococcus aureus will invariably be followed by suppuration under like circumstances. Grawitz and de Bary, on the contrary, have proved that not only the coccus named, but certain irritating reagents and different products of micro-organisms, not necessarily the staphylococcus, different alkaloids, or ptomaines, are productive of pus. Solutions of nitrate of silver, if injected under the skin of dogs, rabbits, rats, and mice, will be harmless if weak, not stronger than .005 of one per cent., but when five per cent. in strength will invariably be followed by abscess in dogs. Neither acids nor alkalies cause suppuration, except the liquor of caustic ammonia, which if introduced in full strength is followed invariably by suppuration. In neither of these instances were there any micro-organisms discoverable in the pus freshly removed from the abscess, or transferred upon nutritive gelatin as a culture medium. Oil of turpentine did not induce pus in rabbits and guinea pigs, even though injected in large quantities, but only inflammation; whereas in dogs subcutaneous injection of oil of turpentine, which is a germicide, was always followed by suppuration.

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* Recent researches in granulating surfaces of the skin by Louis Heitzmann, *Archiv. f. Dermat.*, 1892, have proved that the source of pus is not the capillary loops, but the outermost layer of the myxomatous tissue itself.

"From these experiments it follows that chemical substances entirely free from bacteria and cocci tend to induce the suppurative process in different animals. On the other hand, it has been experimentally proved that in dogs and rabbits the injection of cultures of staphylococcus into the normal subcutaneous tissue will not induce inflammation or suppuration. It is necessary that a tissue first be irritated to a condition of inflammation, by traumatism or by chemical irritants, to have a soil favorable for the development of staphylococcus, which under these circumstances will produce an abscess. Lately P. Grawitz has shown that the subcutaneous injection of a ptomaine derived from putrescent organic material, cadaverine, will always lead to the formation of an abscess.

"From the practical standpoint it is of the utmost importance to work aseptically, or in other words, with such degree of cleanliness that the introduction of micro-organisms or their ptomaines becomes impossible. It is well established that even open fresh wounds, if aseptically dressed with gauze saturated with a 1:1000 solution of corrosive sublimate and let alone for a few weeks, will kindly heal without one single droplet of pus. Corrosive sublimate and carbolic acid are still most reliable germicides. We are not yet prepared to assert that micro-organisms alone cause suppuration, since there are irritating chemical substances whose introduction into the body may likewise be followed by this process. Recent observers have maintained that there is a marked difference between a mere accumulation of leucocytes and an abscess proper. In the first instance there may be present a serous or fibrinous exudate entangled with a number of emigrated leucocytes, without a loss of tissue, without, therefore, suppuration. In the latter instance a certain amount of tissue is destroyed and directly transformed into pus. If this view be correct, it certainly strongly supports our present notions of the process of suppuration herewith laid down.*

"1. Inflammation is a disturbance of nutrition of a tissue causing a recurrence of the embryonal condition of the tissue involved.

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* Even to-day the question whether or not suppuration is dependent upon the presence of staphylococci or their ptomaines is unsettled. All, however, agree that pus devoid of micro-organisms is bland, harmless, not infectious; pus, on the contrary, contaminated with micro-organisms possesses infectious and poisonous properties in a high degree.

"2. The embryonal condition is established by the breaking up of the tissue into those medullary or indifferent corpuscles which, at an early stage of normal development, have built up the tissue.

"3. The medullary corpuscles arise not alone from the protoplasmic bodies of the tissue, the so-called 'cells,' but the intercellular or basis-substance is also productive of such corpuscles, as these have shared in the formation of basis-substance in the process of normal development.

"4. The medullary or indifferent corpuscles will still represent a tissue so long as they remain interconnected and continuous. By the reappearance of basis-substance simply the most favorable termination is established, the so-called 'resolution.'

"5. If the inflammatory or medullary corpuscles have largely augmented in numbers, thereby remaining in uninterrupted connection, the result will be productive of a newly-formed tissue of increased size, a so-called 'hyperplasia.'

"6. If the inflammatory corpuscles springing from previous 'cells,' basis-substance, and blood-vessels break asunder and become isolated, they will be suspended in an albuminous liquid, and will henceforth represent pus-corpuscles.

"7. Pus, therefore, is a destroyed tissue broken up into its constituent elements, and as such incapable of the production of a new tissue, although the single pus-corpuscles will remain alive and amœboid almost indefinitely as long as they are sufficiently nourished.

"8. The emigration of colorless blood-corpuscles may participate in the formation of pus.

"9. Suppuration is caused by the presence of certain microbes, mainly the three varieties of staphylococcus, only when a previous inflammation is present in the tissue, furnishing a favorable soil for the development of the before-mentioned microbes.

"10. Staphylococcus is not the only antecedent of suppuration, it having been proved by experiments that the introduction of certain chemical agents, unfavorable to the development of microbes, may likewise be followed by suppuration."

CHAPTER XXXII.

INFLAMMATION OF THE GUMS,—ULITIS.

To describe all the diseases of the gums would require a delineation of all the lesions that affect the oral mucous membrane, or rather of the oral cavity,—a task which far exceeds the plan of this work. I shall therefore confine myself to the description of only those diseases which especially interest the dental practitioner, because in direct relation to the teeth.

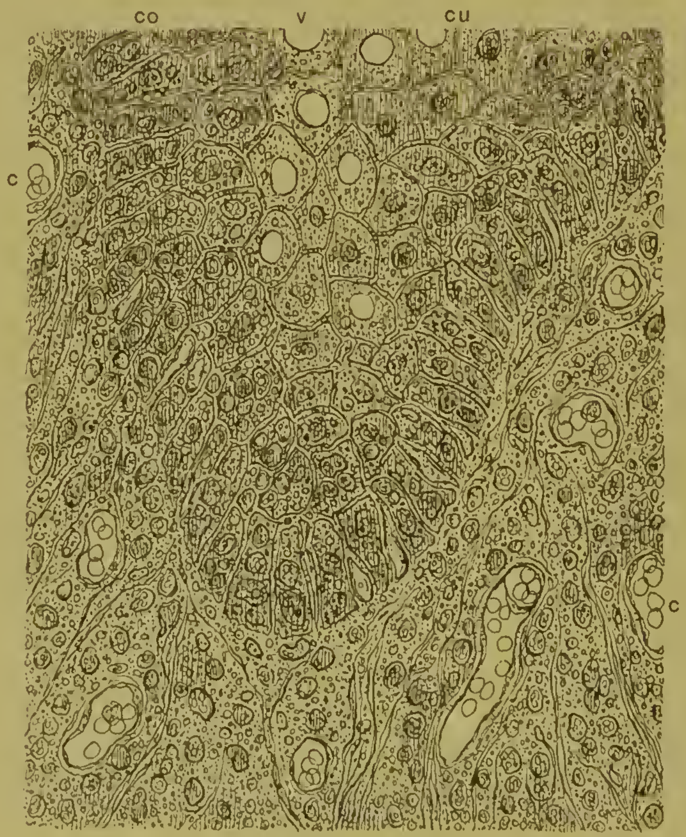
In general *anæmia*, or chlorosis, the gums appear bloodless and pale. Not infrequently they are found in a state of hydropic swelling,—so-called œdema. This condition may be transient, arising from so-called catarrhal stomatitis; it may last for weeks, as after typhoid fever, or for months, as in pregnancy and after delivery; or, finally, it may depend upon a structural change such as is observed in myxœdema of the skin after the destruction or extirpation of the thyroid body.

Hyperæmia of the gums is caused by poisoning with mercury—salivation—or with dyes, as in the manufacture of artificial flowers, one of the most common offenders in the latter case being picric acid. Sometimes we see the condition in pregnant women. The slightest injury to the hyperæmic gums causes bleeding, which feature, together with a bluish-red color, is symptomatic of scurvy.

Ulitis (erroneously termed gingivitis, since the Latin word gingiva ought not to be combined with the Greek termination itis) is of frequent occurrence. It is usually caused by mechanical injuries, such as the wearing of artificial teeth, especially when mounted on rubber plates. In such cases the pressure upon the gums is assisted by a decomposition of the fluids of the mouth and the non-conductivity of the rubber. Another fruitful source of ulitis is the accumulation of tartar, or salivary calculus, on the necks of the teeth, which causes pressure upon the border of the gums, resulting ultimately in their recession from the teeth. Decomposing particles of food at the border of the gums and the tartar, in the space between the gum and the neck of the tooth, which space is usually called a pocket, and the accumulation of staphylococci cause a superficial suppuration of the gum, which process, by the destruction of the alveolar border, hastens the recession of the gum and the exposure of the necks and roots of the teeth, and induces pericementitis.

The image of acute ulitis under the microscope is rather characteristic. (See Fig. 201.) The fibrous connective tissue building up the main mass of the gums is found crowded with inflammatory corpuscles, usually in nests or roundish foci. These inflammatory corpuscles exhibit greatly varying sizes, from a small solid and homogeneous granule or lump to a vacuoled or even a granular and nucleated protoplasmic body. All these forms are known to be different stages of development of the living matter. We can easily satisfy ourselves that not only the protoplasmic tracts between the bundles have produced inflammatory corpuscles by a process of outgrowth and splitting up of the lumps of living matter, but the bundles themselves break up

Fig. 201.



Acute Ulitis.

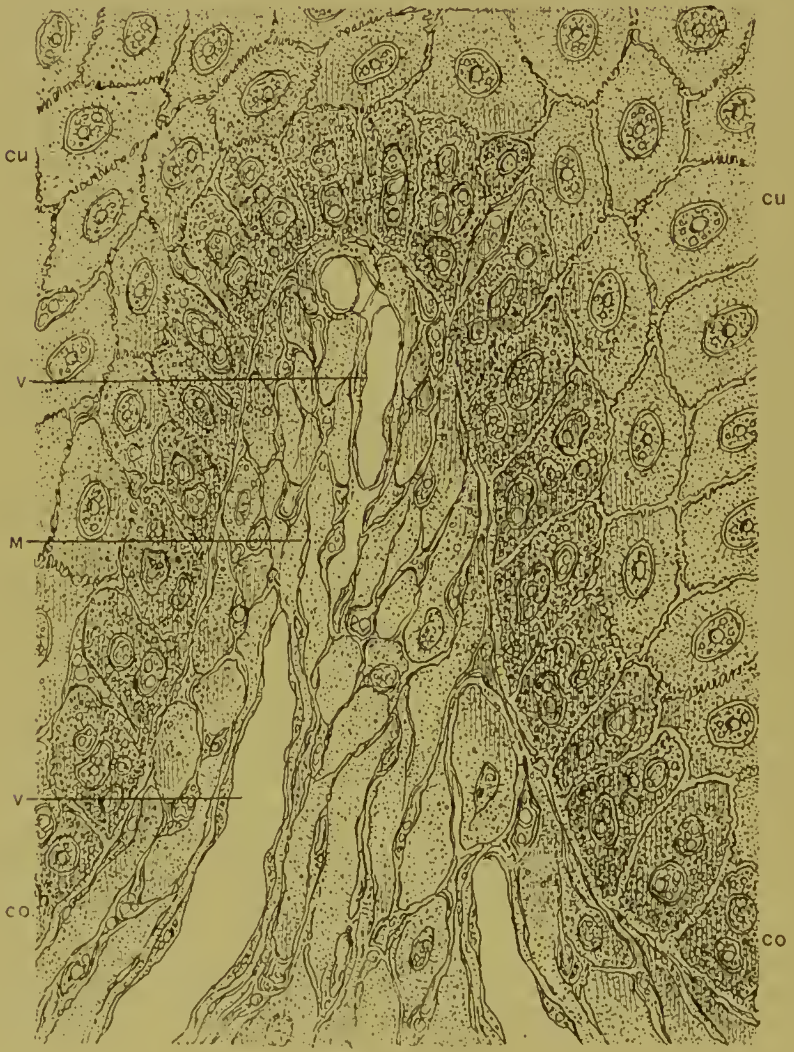
CO, row of columnar epithelia; *CU*, cuboidal epithelia; *C*, *C*, inflammatory infiltration of fibrous connective tissue; *V*, vacuoled epithelia, nucleus dropped out. Magnified 400 diameters.

into rows of inflammatory corpuscles, obviously after the liquefaction of the glue-yielding basis-substance. In consequence of an increase of the living matter, the papillæ at the surface of the connective tissue are considerably enlarged. The blood-vessels, mainly the capillaries and veins, are seen widened and engorged with both red and colorless blood-corpuscles. The stratified epithelial covering of the connective tissue likewise exhibits an outgrowth and a proliferation of the living matter in its protoplasm. In mild cases, such as the illustration demonstrates, only the row of columnar epithelia and the adjacent cuboidal epithelia show the proliferation. Frequently the thorns of living matter interconnecting the epithelia by outgrowth and coalescence produce club- or pear-shaped lumps wedged in between the enlarged epithelia (L. Elsberg). In higher grades of acute inflammation not only the columnar but all the cuboidal epithelia are found to be engaged in proliferation. In the latter the serous exudate frequently accumulates around the nuclei, which, when they drop out in section-cutting, leave an apparently empty space,—a so-called vacuole.

Suppuration of the gum is found either superficially along the borders, caused by the accumulation of tartar, or in the shape of a more or less circumscribed abscess in the depth of the connective tissue. Around the abscess the gums are invariably found in a high grade of œdematous swelling. The most frequent cause of such abscesses is caries of the teeth combined with purulent pericementitis. Sometimes foreign bodies, splinters of bone, bristles of the tooth-brush, particles of the cores of apples or pears, etc., cause abscesses of the gum when a simultaneous infection with staphylococci has taken place.

Hyperplasia of the gum is always the outcome of chronic plastic ulitis, and is of frequent occurrence. In its mildest forms only the papillary layer is rendered hyperplastic, the surface appearing to the naked eye in the form of lobules like strawberries. Too frequent application of the tooth-brush is sufficient to produce such a papillary hyperplasia. Higher grades of chronic ulitis are often seen along the borders of carious cavities, or covering deeply-seated tumors of the jaw of any description. This process is characterized by a new formation of myxomatous tissue, rather freely vascularized and replacing the previous fibrous connective tissue. (See Fig. 202.) The myxomatous tissue in this instance (hyperplastic gum overlapping a cyst) is conspicuous by a large number of protoplasmic tracts producing the myxomatous reticulum with large spindle-shaped points of intersection. In the meshes in the middle of the myxomatous basis-substance we frequently find

FIG. 202.



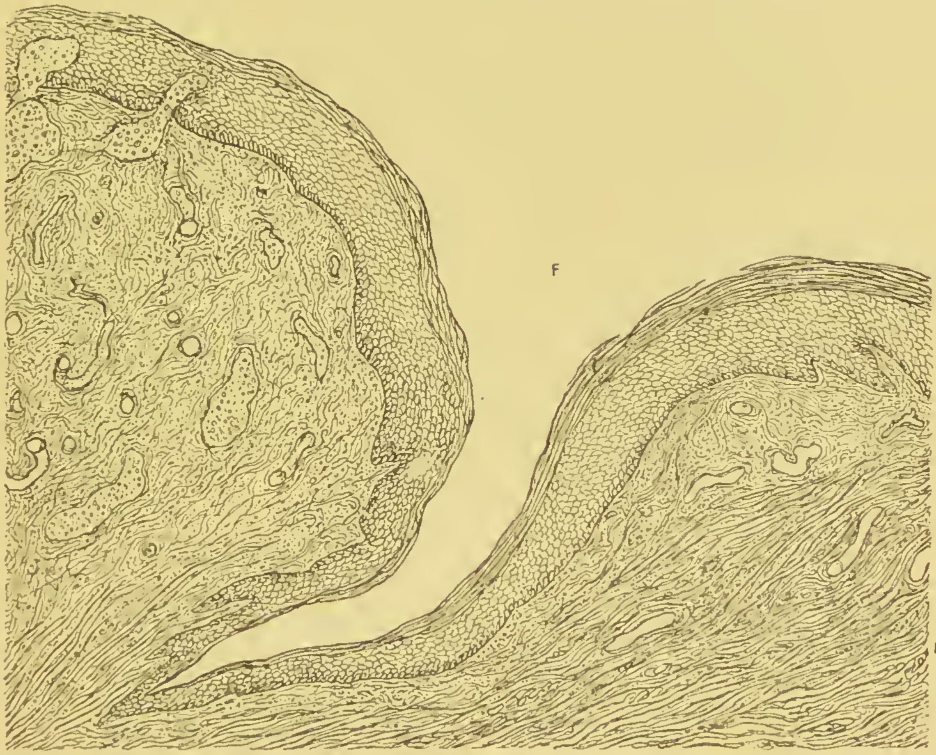
CHRONIC ULITIS.

M, myxomatous tissue of papilla; *V*, *V*, capillary blood-vessels; *CO*, *CO*, row of columnar epithelia; *CU*, *CU*, cuboidal epithelia. Magnified 600 diameters.

protoplasmic bodies. The capillaries of this tissue are conspicuous by their large calibers and their large-sized endothelia along the walls. Most of these blood-vessels are newly formed. The columnar epithelia directly covering the myxomatous tissue are still in a state of proliferation, and here and there we likewise see pear-shaped or branching formations of living matter in the cement-substance.

The highest grades of hyperplasia of the gum are seen in the vicinity of broken roots left in the sockets, and in the neighborhood of large carious cavities. In the former instance pericementitis is the cause of chronic ulitis, whereby lobulated tumors in the mucosa are produced sometimes some distance away from the root. Tumors may even assume the aspect of cancer, but soon after the extraction of the root they disappear without further treatment.

FIG. 203.

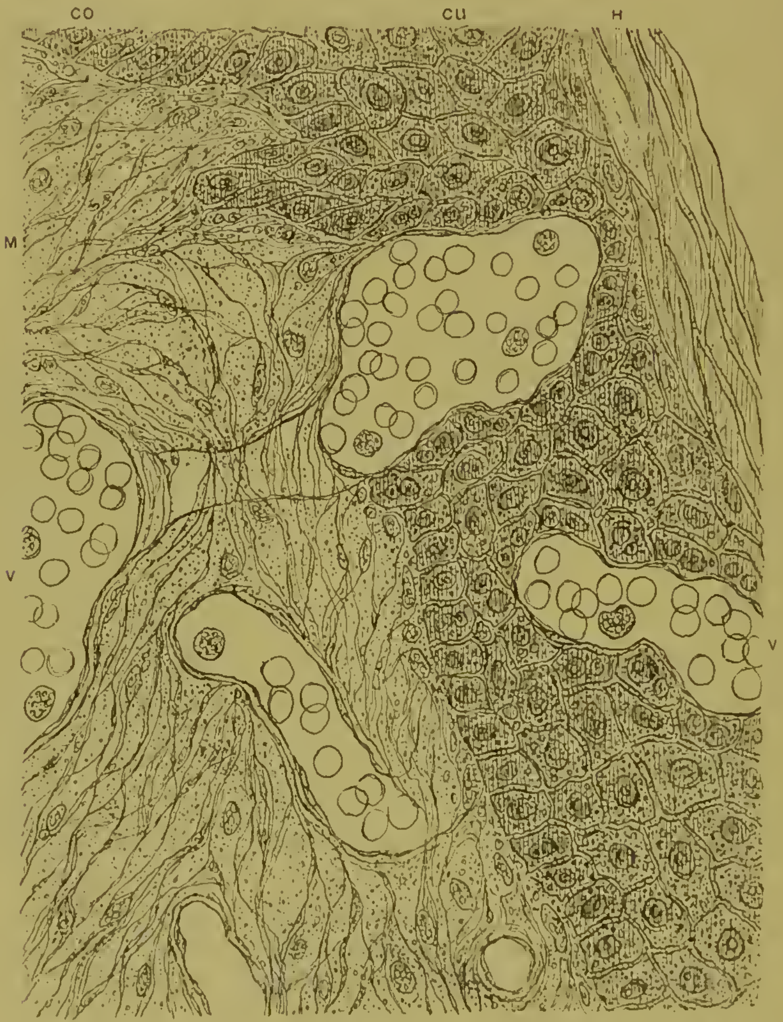


HYPERPLASTIC GUM GROWN INTO THE CARIOUS CAVITY OF A MOLAR.

K, knob of gum of myxomatous structure in the carious cavity; *O*, outer portion of gum; *F* (upper), deep fissure caused by the thin dentinal wall of the cavity; *E*, *E*, stratified epithelium on the surface; *V*, varicose veins in myxomatous tissue, penetrating into epithelial layer; *F* (lower), fibrous connective tissue. Magnified 100 diameters.

When the gums overlap a large carious cavity, or when they penetrate such a cavity through a perforation in the thinned wall of dentine, they produce large lobulated tumors, more or less filling up the cavity. It is not always easy to recognize hyperplastic gums in the carious cavity, especially if the invasion has taken place through a perforation in the dentine concealed from the eye. Hyperplastic gums of this description are of a lobulated surface, lively crimson red color, bleeding easily, and occasionally painful. Fig. 203 illustrates such an instance of hyperplastic gums, separated from the outer portion by a deep

FIG. 204.



HYPERPLASTIC GUM GROWN INTO THE CARIOUS CAVITY OF A MOLAR.

H, flat epithelia of horny layer; *CU*, cuboidal epithelia; *CO*, columnar epithelium in oblique section; *M*, myxomatous connective tissue; *V*, *V*, varicose veins penetrating into the epithelial layer. Magnified 500 diameters.

fissure, evidently caused by a thin layer of dentine bordering upon the perforation, through which the gum found its way into the carious cavity. The portion filling up the cavity is, to a great extent, myxomatous; in the outer portion the myxomatous structure is present only at the surface. A striking feature of the inner portion is the presence of varicose veins at the surface, penetrating into the stratified epithelium. Fig. 204 represents this rather peculiar occurrence. Here we see that the varicose veins have, by a gradual pressure, destroyed a number of epithelia, bulging on the surface and being covered only by a few layers of epithelia. This fact explains why gums in the condition described bleed so readily and so profusely, sometimes after the slightest injury.

Ulceration of the gums in the shape of shallow losses of substance, coated with a whitish exudate, and sharply circumscribed, is not rare. Such ulcers are termed "*aphthæ*," popularly *canker sores*. Their etiology, according to E. Frankl, is based upon an invasion of Staphylococci pyogenes citreus and flavus. In regard to the cause of this trouble but little is known. Some authors believe the disease to be mainly the result of uncleanliness, and principally confined to childhood, and to those whose food consists largely of milk. It is certain, however, that derangements in the digestion, anæmia, rhachitis, as well as pregnancy and the menstrual period, greatly enhance a predisposition to the infection. The writer has a patient who, almost every month shortly before the appearance of her monthly periods, for several years was troubled with aphthæ. These patches are most commonly observed upon the gums in the vicinity of the apices of the roots of cuspids and bicuspids, where the mucous membrane of the cheek joins that of the gums. They are also seen under the tongue on either side of the frænum. In the beginning we notice them as one or more roundish spots, about the size of a pin-head. These spots at first are separated from one another by a dark red line encircling each place. In later stages the small patches unite into one, usually assuming a more or less oblong shape. The patients frequently complain of great pain during mastication and deglutition, according to the location of the trouble.

Syphilis likewise causes ulcers upon the gums, especially in its later stages, when shallow ulcers, much resembling aphthæ, sometimes appear symmetrically. Such ulcers, which likewise are characterized by pains in the ingestion of acid foods, may indeed be mistaken for aphthæ. Even their causation by syphilis is in many cases doubtful. The dark-red border around the ulcer is said to be characteristic of a syphilitic origin. The scars left after the ulcers have healed, so-called *leucoplakia*, likewise in many instances present an appearance which makes the origin of the trouble dubious. Intense salivation, following the misuse of mercury in previous years, has often led to an ulcerative destruction of the gums. To-day, however, when mercury is administered under great precautions, and salivation is not allowed to pass beyond its initiative stages, such an occurrence is rare.

Scurvy in its highest grades may produce ulcers on the gums, characterized by a bluish-red base and easy bleeding. The œdematous swelling around scorbutic ulcers is always intense.

Diphtheritic ulcers of the gums, caused by a specific bacillus (Klebs-Löffler), are rarities: so are tuberculous ulcers, which are caused by the tubercle bacillus (Koch).

Gangrene of the gum is caused either by *noma* or by *stomatitis*. It rapidly destroys large masses of tissue, mainly at the buccal surface of the oral cavity. The micro-organism causing this disease is probably the same as that of splenic fever. In intense salivation due to overdoses of mercury, and in high degrees of scurvy, gangrene of the gum has likewise been observed.

CHAPTER XXXIII.

INFLAMMATION OF DENTINE,—EBURNITIS.*

It is a well-known fact that dentine becomes the seat of an inflammatory reaction by caries, as well as through the gradual destruction of the roots caused by alveolar pyorrhœa, whereby (in the latter instance) first the cementum and afterward the dentine are destroyed. Another instance of an inflammatory invasion of dentine is observed during pulpitis, where first the secondary and afterward the primary dentine are destroyed by an inflammation of the pulp-tissue. Aside from these secondary forms of inflammation, there occurs a primary inflammation in dentine, independent of pulpitis or pericementitis, running its course in the middle of the dentinal tissue, and leading, as all inflammatory processes do, either to a new formation or to destruction by suppuration. This primary inflammation of dentine is the subject of this chapter.

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* "Inflammation of Dentine." By C. Heitzmann and C. F. W. Bödecker. *Independent Practitioner*, 1886.

As to the causes of "eburnitis," as we propose to term this process, there are a small number of cases in which nothing can be observed that would account for an inflammatory reaction in the dentine, which, although alive, is far away from the blood-vessels throughout. In a few specimens we observed nothing anomalous in the soft parts surrounding the root of the tooth, nor in the pulp-tissue. Some preparations exhibited a slight degree of pericementitis, with the characteristic superficial erosions of the cement-tissue. In other cases we noticed a layer of secondary dentine, indicative of an increased activity of the pulp-tissue, although no pulpitis was visible. In all cases of eburnitis, however, we observed in the dentinal tissue itself a striking feature: an incomplete calcification of the dentine, and a great abundance of interglobular spaces, signifying a malformation and an incomplete calcification of the basis-substance. This accounts for its greater vulnerability and susceptibility to irritative processes. The enamel, in ground specimens, will likewise show abnormalities, such as pigmentation, stratification, or insufficient deposition of lime-salts.

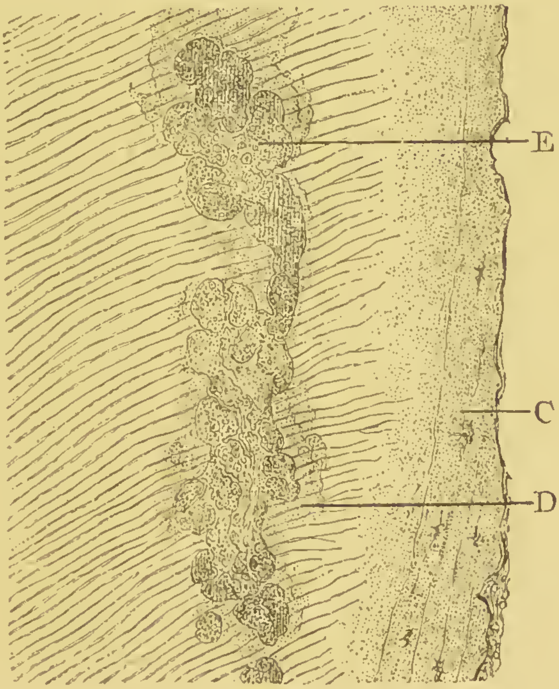
Far greater are the number of instances in which traumatism has led to an inflammation of the dentine. It is evident that any surgical interference, such as burring or excavating, will in an otherwise normal dentine produce irritation sufficient to result eventually in an inflammatory reaction. If, in addition to excavating, a caustic is applied or a filling inserted, which may exert a certain amount of irritation, inflammation of the dentine may follow.

We know, from practical experience, that when a caustic in the form of an oxychloride or an oxyphosphate filling is applied to very sensitive dentine, this tissue, in the course of time, will become less sensitive through the partial obliteration of the canaliculi in the dentinal wall of the cavity. The filling-material in this manner excites an irritation, which in the course of months or years results in a new formation of dentine around the filling, and this is often denser than the original dentine. This hardening, as the most favorable result of traumatism, is the consequence of a reaction of the dentine, known under the term of consolidation. On the other hand, instances are not rare in which the insertion of an oxyphosphate, oxychloride, or a gold filling has given rise to excruciating pain, sometimes even necessitating the removal of the filling. The latter result is due to intense irritation of the dentine, manifested probably through the medium of the dentinal fibers encroaching upon the pulp-tissue. Such unfavorable results are met with mainly in patients whose teeth are badly calcified, or in temporary teeth, in which the amount of living matter is much greater than in the average permanent teeth.

The best known example of the effects of traumatic injuries upon dentine is seen in the elephant's tusk in which a bullet has lodged. The remarkable changes of the dentine around the bullet are well known to scientists as well as mechanics. As early as 1798, the great German poet and philosopher, Goethe, investigated the subject of diseased ivory from the elephant's tusk, resulting from the impaction of iron or leaden balls; the process appeared to him to be a sort of coagulation (Gerinnung); he also mentions the occurrence of exostosis upon the wall of the pulp-cavity, in cases where a ball entered the posterior, weak and hollow portion of the tooth.

In order to realize the structural changes in inflammation of the dentine, let us remember that it, like bone, is a living tissue. The analogy between these two tissues is clearly established by the fact that in the development of bone-tissue we observe globular territories, the same as in the formation of dentine. In the former instance every territory contains one or more bone-corpuscles, with their offshoots (lacunæ and canaliculi), whereas in the dentine the territories are pierced by the canaliculi and their tenants, the dentinal fibers. The basis-substance in both these tissues is traversed by a large amount of living matter, in the shape of a delicate reticulum, the meshes of which are filled with the calcified basis-substance proper. The study of the history of development of bone and dentine reveals a striking similarity in the formation of both of these tissues. The osteoblasts are preliminary formations in developing bone-tissue, in the same manner as are the odontoblasts at the periphery of growing dentine. All attempts to explain the development of dentine directly from the odontoblasts have proved unsuccessful, as neither the formation of the basis-substance nor that of the dentinal fibers could ever be brought in accordance with the elongated odontoblasts, whereas the development of the dentine becomes plain if we take the ground that the odontoblasts break up into medullary corpuscles, between which the dentinal fibers are formed. If the odontoblasts should calcify directly, we would be at a loss to understand the formation of globular territories in fully-developed dentine. If, on the contrary, we accept the formation of basis-substance from medullary corpuscles, the appearance of globular territories becomes plain. Nothing is required but a group of medullary corpuscles, which are transformed into basis-substance, while the larger threads of living matter, known as Tomes's fibers, traverse the rows of medullary corpuscles, taking their course between them. Six years' study of the history of development of the teeth, especially of specimens of the sixth month of intra-uterine life, when dentine begins to form, has led to the conviction stated above.

Fig. 205.



Eburnitis. Neck of Tooth.

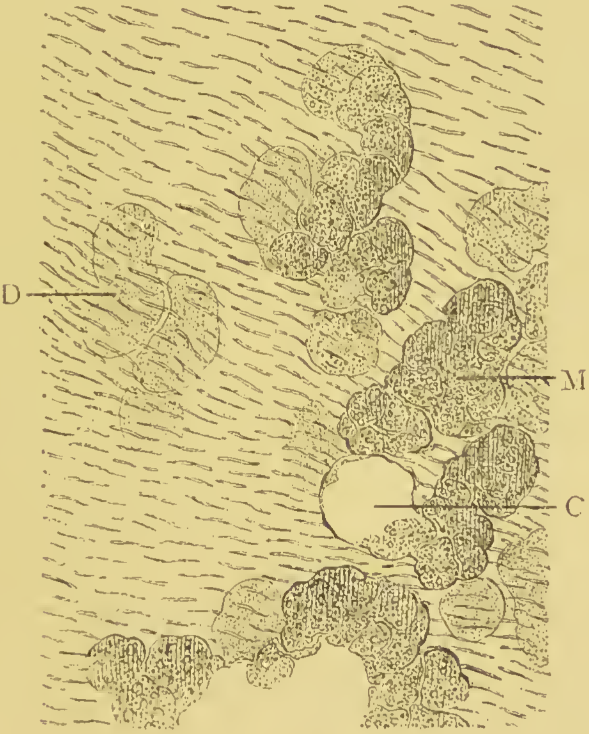
C, cementum, with shallow excavations at its periphery, caused by pericementitis; *D*, dentine in the beginning of dissolution of lime-salts; *E*, protoplasmic masses in globular territories. Magnified 200 diameters.

Inflammation causes a solution of the lime-salts, and afterward a liquefaction of the basis-substance, both in bone and dentinal tissue. The result will be the appearance of globular spaces, or bay-like excavations, which, instead of being filled with basis-substance, exhibit medullary corpuscles, or multinuclear protoplasmic masses, corresponding to the embryonal stage of the inflamed tissue. (See Fig. 205.) The excavations of the dentine are identical with those seen in the process of absorption of the dentine of temporary teeth, and those of secondary dentine in the neighborhood of an inflamed pulp. The diagnosis of primary eburnitis becomes established, not by the appearance of such excavations, but by their presence in the middle of the dentine without any connection with the surface, or with the pulp-chamber of the tooth.

The earliest feature of eburnitis under the microscope is the appearance in the middle of the dentine of bay-like excavations of varying sizes, and separated from one another by glistening ledges. At first the dentinal canaliculi and their tenants (the Tomes fibers) remain recognizable within the basis-substance. In the next stage only dentinal fibers remain discernible, the contours of the canaliculi being lost, while the basis-substance itself looks irregularly granular. The difference in the refraction of light of these globular spaces, as compared with normal dentine, indicates a dissolution of lime-salts within them. In a still later stage the entire basis-substance is transformed into a granular mass, which is easily stained by an ammoniacal solution of carmin. The globular spaces appear to be filled with multinuclear protoplasmic masses, or with a number of medullary corpuscles, more or less coarsely granular, and flattening each other to some extent. These features, therefore (as mentioned), are identical with those observed in absorption of temporary teeth, the only difference being that the latter process starts from the periphery, whereas eburnitis begins in the middle of the dentine, without any direct connection with the outer surface or the pulp-cavity of the tooth, and often at the border of cavities that have been previously filled. (See Fig. 206.)

The origin of the globular fields of dissolution in temporary teeth, in some instances, may be questioned, since it is admitted that they are simply the results of the dissolution of the lime-salts, while their filling in with medullary corpuscles may be caused by immigration from without. But in most of the specimens of eburnitis which we have examined, no doubt was left as to the primary origin of the spaces and their contents within the dentine, for many of them were isolated, and sometimes far apart from the original seat of inflammation and far from the pulp-chamber as well as the periphery of the tooth. In connection with eburnitis we have noticed frequently that the crowns of teeth thus affected were surrounded by defective enamel. There can be no doubt that the medullary corpuscles present in these spaces have really grown from dentinal tissue, respectively from the living matter of the dentinal fibers and of the basis-substance.

Fig. 206.



Eburnitis. Crown of Molar.

D, beginning dissolution of lime-salts in the middle of dentine: *M*, medullary corpuscles filling the globular spaces that have arisen from inflamed territories of dentine; *C*, cavity in the dentine, whose contents had been dragged out. Magnified 500 diameters.

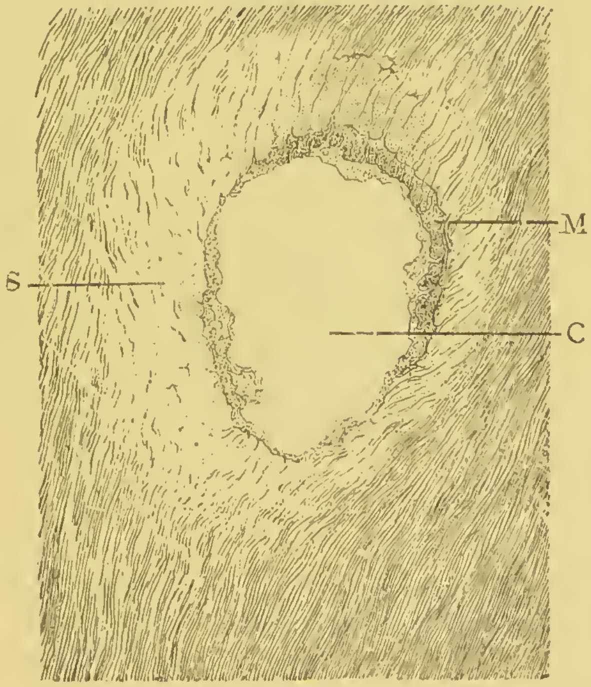
In some of the specimens, especially in the central portions of somewhat larger cavities, the medullary tissue had been removed by the process of grinding or cutting. Where, however, they had been left *in situ*, the medullary corpuscles appeared interconnected by means of delicate offshoots, representing an embryonal tissue; or no distinct boundary lines were seen between the medullary corpuscles, the whole filling of a globular territory being a uniformly granular protoplasmic mass, with interspersed nuclei. We cannot deny the possibility that by the breaking apart of these medullary corpuscles pus may be formed in the middle of the dentine, thus representing an abscess independently of the pulp-tissue. Wedl and Albrecht take the presence of blood-vessels, presumably grown into the dentine from the pulp, for an absolute necessity in cases of abscess of the dentine. Such a presumption is superfluous, in our opinion, for we assert the dentine to be a living tissue, and as such capable of primary inflammation, nay, suppuration, without the direct co-operation of blood-vessels. We fully believe in the possibility that a so-called pyogenic membrane could even form around the abscess without a direct supply of blood-vessels. If it is claimed that an abscess in the dentine must form originally in connection with the pulp-tissue, and afterward be separated from the latter, we deny any such necessity, since we claim the possibility of the formation of a primary abscess in the dentine, independently of the pulp-tissue.

Far more common than suppuration, however, is the healing process of eburnitis, the results of which may be either a new formation of dentine, closely resembling secondary dentine, or a dentine which is destitute of canaliculi, representing what some authors have termed osteo-dentine. We meet with places in the dentine, more especially in the neighborhood of fillings of some years' standing, wherein the dentine is largely composed of calcified basis-substance, and the dentinal canaliculi are arranged in bundles more or less separated, but of a normal appearance. It is obvious that here the recalcification of the previously inflamed dentine was most perfect, producing a tissue which is harder and richer in lime-salts than the original dentine.

In another instance, the newly-formed tissue closely resembles secondary dentine, with few, irregularly-scattered, wavy canaliculi, and large territories of calcified basis-substance, destitute of canaliculi. Sometimes the basis-substance may be uniform in structure, or composed of globular fields or territories. The tissue as such under the microscope could not be distinguished from secondary dentine; the fact, however, that it is found far from the pulp-chamber, in the middle of otherwise normal dentine, proves that it is the result of a previous inflammatory process of the dentine. Here the calcification still attained a high degree of perfection, so desirable from the practical standpoint, although morphologically not as perfect as in the first instance. Fig. 207 illustrates this form of healing process in eburnitis. Here the cavity, whose soft medullary contents had been dragged out in the process of grinding, is surrounded by a tissue bearing all the characteristics of secondary dentine.

Another result of eburnitis is the re-formation of the basis-substance, composed of small globular masses, between which are visible irregular and widened canaliculi. It is obvious that calcification in this instance is deficient, and consequently the newly-formed dentine is less consistent than normal dentine. In one of our specimens, dentine of a temporary tooth, we observed not far apart two spots, one of which shows a large amount of basis-substance, with scanty and narrow canaliculi, whereas another spot was in the condition before described,—viz, imperfectly calcified. The latter portion exhibited well-marked globular territories all around a cavity, which probably contained medullary tissue, before subjection to the process of grinding. Some territories contain numerous and wide canaliculi, others scarcely any. Crystals of hæmatoidin indicate the inundation of the inflamed tissue with blood, in the acute stage.

FIG. 207.



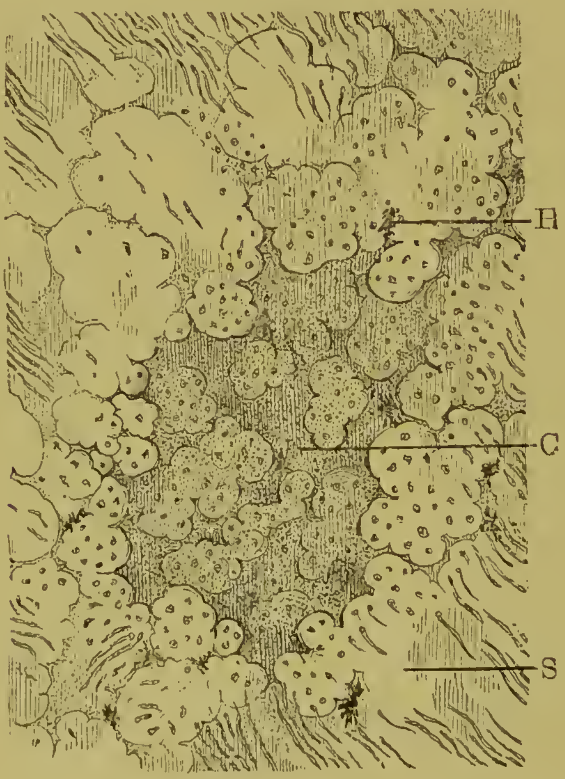
HEALING OF EBURNITIS. CROWN OF MOLAR.

C, empty cavity; *M*, medullary tissue, at the border of the cavity, partly calcified; *S*, secondary dentine, with scanty and irregularly-scattered canaliculi. Magnified 100 diameters.

As this cavity was near the pulp-chamber, the saturation of the tissue in consequence of a hemorrhage is explicable. (See Fig. 208.)

In a fourth instance of eburnitis the healing process is rather poor. No new canaliculi are formed, but the whole field is traversed by irregular, angular, branching spaces, with numerous radiating offshoots, bearing a close resemblance to bone-corpuscles. The presence of such spaces gave rise to the term "osteo-dentine," applied by previous authors. We would agree with this term if the restriction be added, that in these instances no regular bone-tissue is combined with dentine, but only a tissue resembling bone. The spaces are filled either with medullary corpuscles, or a homogeneous basis-substance, or highly refracting globular masses, the result of a recent but rather imperfect deposition of lime-salts. The basis-substance between these spaces is likewise composed of globular calcified masses, between which we observe branching offshoots of the spaces. The

FIG. 208.

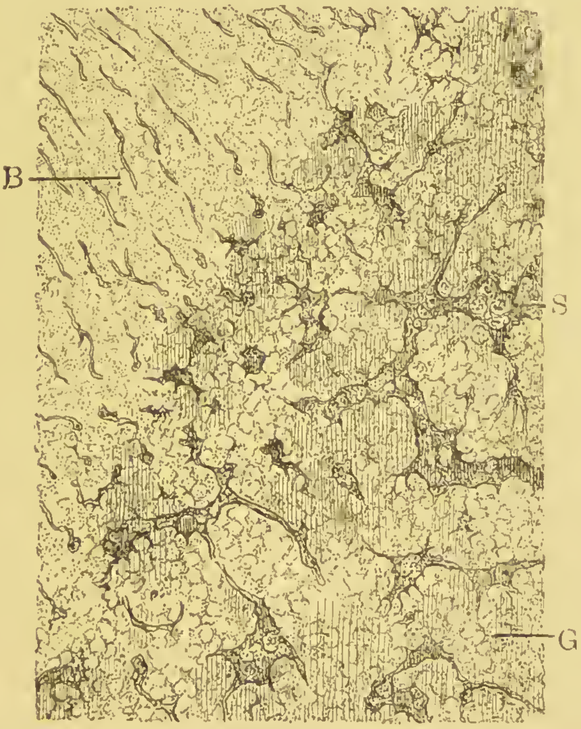


HEALING OF EBURNITIS. CROWN OF BICUSPID.

C, cavity bounded by globular territories, between which there are uncalcified interglobular spaces; *S*, secondary dentine; *H*, crystals of rust-brown hæmatoidin. Magnified 500 diameters.

periphery of a spot of healed eburnitis may show small spaces scantily scattered in the basis-substance, whereas the central portions may exhibit very large spaces and comparatively little basis-substance. Fig. 209 illustrates such a termination of eburnitis, one portion showing a tolerably well-developed secondary dentine, other portions a poorly-calcified, so-called osteo-dentine, in which the peripheral zones are decidedly richer in lime-salts than the central ones. Evidently the healing process of eburnitis is poorest in the last instance, leading, as it were, to the formation of a comparatively soft, brittle, and crumbling dentine, lacking the elasticity of the original tissue, and not entitled to the name of dentine proper. From the description given of healed eburnitis around gun-balls in elephants' tusks, it is obvious that the mass, as described as a result of "consolidation" or "coagulation," etc., is such a poorly-calcified dentine, or osteo-dentine.

FIG. 209.



HEALING PROCESS OF EBURNITIS. ROOT OF MOLAR.

B, secondary dentine, with scanty canaliculi and a globular basis-substance; *S*, spaces resembling bone-corpuscles, with very irregular, branching offshoots; *G*, globular depositions of lime-salts in the basis-substance. Magnified 500 diameters.

CHAPTER XXXIV.

PULPITIS IN ITS CLINICAL ASPECTS.

Many disturbances, such as certain forms of pericementitis, necrosis, etc., are the result of primary pulpitis that has caused the death of the dental pulp. The pain which usually accompanies pulpitis is, as a rule, severe, though not always localized. The dental pulp being richly supplied with nerve-fibers and blood-vessels, at the same time inclosed in an unyielding wall of dentine, is unable to swell. Even a comparatively slight inflammation may cause considerable pressure upon the nerve-fibers,—pressure which manifests itself either as pain in the affected tooth, or as neuralgia in other parts of the nervous system. The severity of the pain in pulpitis is not so much dependent upon the changes occurring in the pulp-tissue, as upon external influences and constitutional peculiarities of the patient. We often meet with pulps in which the inflammation is slight, while the pain caused thereby is severe. On the other hand, we observe cases in which even an extensive pulpitis causes comparatively little or no pain. Occasionally we see patients, most of whose teeth are broken and decayed, who declare, nevertheless, that they have never had toothache, while in other instances patients suffer pain as soon as the caries has penetrated the enamel of the tooth.

The etiology of pulpitis may be classified under the following heads:

Dental caries;

Invasion of the pulp by micro-organisms (staphylococci and streptococci);

Pressure of filling-materials placed too near the pulp:

Mechanical violence, or traumatism;

Fracture of the tooth;

Pericementitis;

New formations in the pulp-tissue;

Constitutional disturbances;

Sudden thermal changes;

Electrical shock.

The exciting cause of pulpitis may be one of the above category of causes, or a combination of several of them. The most frequent is unquestionably caries. In the process of caries micro-organisms in the dental canaliculi enter in advance of the zone of decalcification, and this explains the occurrence of inflammation in pulps which are not as yet exposed. In many instances we find that the dentine covering the pulp in a carious cavity is quite hard, and one-half of one millimeter, or even more, in thickness. Nevertheless, should the tooth be extracted, we may meet with an inflamed pulp in it. In this instance the exciting cause is an invasion of micro-organisms into the pulp-tissue through the portion of the dentine covering the pulp in the vicinity of the carious cavity. Sometimes this layer of dentine is, though thin, quite healthy, and a gold filling hammered into the cavity may produce inflammation of the pulp, not only by reason of the pressure exerted in the introduction of the filling, but also through the thermal changes resulting from the contact of the metal with the thin layer of dentine covering the pulp. The same may be the result after the introduction of an amalgam filling under the above conditions. The irritation, however, will be much greater should the filling-material be oxychloride or oxyphosphate of zinc. In the latter instance, as soon as the filling is introduced, the patient usually experiences considerable pain, which may last from one hour to one or two days, or until the filling-material is removed.

Exceptionally we may induce pulpitis in the process of regulating teeth, when the force employed has been too great or too rapid. Pulpitis may be the result of a heavy or too long-continued malleting in the introduction of gold fillings, or of the driving of wooden or metallic wedges between the teeth. We also observe pulpitis in consequence of traumatisms, when portions of the crown of a tooth are broken off, and the pulp becomes more or less exposed. New formations of bone or dentine—so-called pulp-stones—sometimes become a source of irritation to the pulp-tissue. As a rule, so long as these newly-formed tissues are developed upon the walls of the pulp-chamber in contact with the primary dentine, they do not cause irritation. Quite different, however, is the outcome of new formations of bone or dentine, when they originate in the middle of the pulp-tissue, in which situation they often produce pulpitis. They may give rise to neuralgia which frequently is obscure and more pronounced in other parts of the nervous system than in the affected dental pulp.

Constitutional disturbances, especially those interfering with the circulation of the blood, occasionally produce pulpitis. Among these I would mention anæmia as the most frequent. In circumscribed pericementitis the inflammatory infection may reach the apex of the root of a tooth, and thus induce pulpitis. Heat, cold, and electricity are remedial agencies frequently employed to abate inflammation, but when applied to the teeth in higher degrees, or suddenly, they also may produce pulpitis.

To the dental practitioner it is of the utmost importance to be able to make a correct diagnosis of the diseases of the pulp, that he may decide upon the proper mode of treatment. First of all, it will be necessary to classify the diseases, in order to differentiate between them. For this purpose most of the classifications of pulpitis are rather unsatisfactory. From a pathological point of view, we have to consider only two principal forms of inflammation,—viz, the acute and the chronic. From a clinical standpoint, on the other hand, it is advisable to formulate a more definite classification of the diseases of the dental pulp. Adolph Witzel* distinguishes varieties of pulpitis in the following manner: 1. Irritation of the pulp, or primary hyperæmia; 2. Partial pulpitis; 3. Total pulpitis with abscess; 4. Suppuration and fatty degeneration of the pulp; 5. Inflammatory gangrene of the pulp. The classification of J. Arkövy,† in Europe, has been accepted by several of the later writers. He was the first to state that most of the diseases of the pulp originate independently, while formerly it was believed that all chronic forms of pulpitis developed from a primary acute inflammation. Arkövy's classification is as follows: I. *Acute pulpitis.* 1. Septic superficial acute pulpitis: 2. Partial acute pulpitis; 3. Total acute pulpitis; 4. Purulent partial acute pulpitis; 5. Acute traumatic pulpitis. II. *Chronic pulpitis.* 1. Chronic parenchymatous pulpitis; 2. Chronic total purulent pulpitis: 3. Chronic hypertrophy of the pulp: *a*, granular, *b*, sarcomatous; 4. Gangrene of the pulp: 5. Total gangrene of the pulp: 6. Chronic idiopathic pulpitis (*s.* concrementalis).

The pathology of the process of irritation has been dwelt upon in Chapter XXV, without reference to its clinical aspect.

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* "Die Antiseptische Behandlung der Pulpakrankheiten." Berlin, 1879; and "Compendium der Pathologie und Therapie der Pulpakrankheiten." Hagen in W., 1886.

† "Diagnostik der Zahnkrankheiten." Stuttgart, 1885.

While, from a pathological point of view, we cannot embrace this process in the chapter on pulpitis, clinically considered it belongs in the latter chapter. Arkövy and Rothmann classify irritation of the pulp as pulpitis, and call it "*acute septic superficial pulpitis.*" I cannot agree with them, as the word pulpitis implies a process in which the pulp-tissue undergoes marked changes, visible under the microscope. The process which both these authors describe as acute septic superficial pulpitis does not, according to their description, exhibit any tissue-changes in the pulp, but merely an invasion of micro-organisms, and is, therefore, in strictness, nothing but an irritation of the pulp. I therefore agree with Witzel and Baume as to this point, and will call this disturbance "*irritation of the pulp,*" though for convenience in a clinical consideration, I shall classify it with pulpitis. According to general principles in morbid anatomy, we will classify diseases of the pulp under the following headings:

I. Irritation of the Pulp.
II. Acute Pulpitis.
  1. Non-purulent.
    a. partial.
    b. total.
  2. Purulent.
    a. partial.
    b. total.
III. Chronic Pulpitis.
  1. Hyperplastic.
    a. partial.
    b. total.
  2. Purulent.
    a. partial.
    b. total.
IV. Gangrene of the Pulp.
    a. moist.
    b. dry.
V. Degenerations and Atrophies of the Pulp.
    a. calcifications.
    b. eburnification and ossification.
    c. sclerotic atrophy.
    d. reticular atrophy.
    e. fatty degeneration.
    f. pigmentation.

I. IRRITATION OF THE PULP.

When caries approaches the pulp-chamber, irritation of the pulp ensues. A tooth may decay, and the process reach a small portion of the pulp-chamber, yet the pulp may not react beyond the stage of irritation. The same conditions sometimes occur in teeth affected by mechanical abrasion and erosion. Fracture, mechanical violence to the teeth, or pericementitis may likewise irritate the pulp. Quite frequently this trouble originates from eburnification and ossification of the pulp-tissue, the pathological anatomy of which is described in Chapter XXVI. Constitutional disturbances also are known to have the same effect upon the pulps, and sometimes even in teeth without mechanical abrasion, erosion, or carious defects.

Diagnosis.—The affected teeth may be slightly sensitive in mastication; if decayed, the cavity rarely extends to the pulp-chamber, the layer of dentine interposed between pulp and carious cavity, although quite thin, being usually hard. In rare instances the pulp may be exposed on one of its horns by caries, and apparently but irritated, when, nevertheless, slight pressure upon it by means of a piece of cotton produces but momentary pain.

The subjective phenomena of irritation of the pulp are characterized by intermittent, sub-acute, drawing pain, mostly lasting a few minutes at one time. The pain usually originates suddenly, when the tooth comes in contact with anything hot, cold, salty, sweet, or sour, or when foreign substances are pressed into the carious cavity. The crowns of teeth not being affected by caries, erosion, or mechanical abrasion, the pulps being irritated by pulp-stones, or in consequence of constitutional derangements, the patients mainly complain of a sensation of uneasiness in all the teeth or the jaw of the affected side. This sensation may sometimes be associated with slight neuralgic pains in other parts of the nervous system.

Differential Diagnosis.—There are two diseases of the pulp showing symptoms somewhat similar to those of irritation of the pulp,—viz., *acute partial pulpitis*, and *sclerotic atrophy of the pulp*. Acute partial pulpitis, however, rarely exists unless the pulp be exposed by caries, except when irritation is due to pulp-stones or constitutional disturbances, which frequently occur in otherwise sound teeth. In the latter case, it is not always possible to state, with any degree of certainty, whether a pulp be merely irritated, or whether slight partial acute pulpitis be present. When the affected tooth contains a carious cavity, it should be carefully examined, especially in the vicinity of the horns of the pulp, which will usually lead to the proper diagnosis.

Sclerotic atrophy of the pulp also may be confounded with irritation of the pulp, but clinically we are unable to differentiate between these two diseases.

The prognosis of irritation of the pulp is quite favorable in carious teeth, as the removal of the cause, by disinfecting and filling the cavity, always effects a cure, although Arkövy mentions that sometimes after filling teeth whose pulps have been irritated, partial or total gangrene may follow,—a result which the writer never has observed.

II. ACUTE PULPITIS.

1. **Non-Purulent.**—*a.* Partial Acute Pulpitis.—*Diagnosis.*—In a pulp slightly exposed, an acute partial inflammation usually results. After the removal of the carious dentine from the cavity of the tooth, we can easily ascertain if the pulp has become exposed in a small place, the exposure usually being situated over one of the horns. In a few instances the pulp may still be found covered by a very thin layer of comparatively healthy dentine. The slightest pressure upon this thin layer of dentine, even with a round instrument, will yield considerable pain. In these instances, therefore, it is advisable to introduce into the cavity of the tooth a small piece of cotton, upon which slight pressure may be exerted without danger of injuring the pulp. When, in the examination of a tooth affected with partial acute pulpitis, the pulp becomes wounded, bright-red blood flows from the pulp-chamber. Percussion will sometimes elicit a sound slightly different from the normal in a tooth affected with partial acute pulpitis, but does not increase the pain during a paroxysm.

Subjective Phenomena.—The pains produced in partial acute inflammation of the pulp are of an intermittent character. The attacks last from five minutes to an hour, but during the intervals the tooth feels comfortable, though slightly sensitive to thermal changes, especially to cold. The paroxysms of pain mostly occur once or twice in twenty-four hours, and usually not until five or seven o'clock P.M., unless during mastication food has become pressed into the cavity of the tooth. When the tooth has been subjected to extreme thermal changes or other irritating agents, the pain is often quite acute, but soon ceases upon the removal of the irritant. In this form of pulpitis the patient usually is able to locate the pain in the affected tooth; and reflex phenomena in other parts of the nervous system rarely accompany the malady.

Differential Diagnosis.—Partial acute pulpitis may be confounded with total acute pulpitis, but in the latter instance the pulp is usually exposed largely or in more than one place. If the pulp-cavity of a tooth affected with total acute pulpitis be opened, the blood oozing forth will have the color not of arterial but of venous blood. The paroxysms of pain are more frequent, and last longer than in partial pulpitis. In total acute pulpitis the tooth is more sensitive to hot than to cold substances; percussion of the tooth elicits a distinctly dull sound, and is slightly painful.

With partial acute pulpitis, gangrene of the pulp may be confounded, as the subjective symptoms of both diseases are similar, although in gangrene of the pulp we notice a characteristic fœtid odor as soon as the pulp-chamber is opened.

The prognosis in partial acute pulpitis is usually favorable for the preservation of the pulp, provided the inflammatory process has existed only a short period, and has only extended over a small area of the pulp-tissue.

b. TOTAL ACUTE PULPITIS.—*Diagnosis.*—In this form of pulpitis the tooth generally is much decayed, and the pulp largely exposed in one or more places. Sometimes we find the pulp not quite exposed, though the carious cavity is large. In these instances, if a total acute inflammation be present, the dentine between the pulp and the carious cavity is found quite soft and thin. If the carious dentine be removed from the cavity and the pulp-chamber opened, dark venous blood flows from the pulp-chamber. Percussion upon the affected tooth always elicits a somewhat dull sound, and is at the same time slightly painful.

Subjective Symptoms.—The pain in total acute pulpitis is intermittent but severe, the paroxysms lasting from one to six hours at a time, and the painless intervals, as the disease progresses, becoming shorter, in the same ratio as the pain during the paroxysms is increased. Irritants, or pressure into the carious cavity, produce severe pain, lasting an hour or more. The patient usually complains of pain on the whole side of the face, and is unable to locate it. Often reflex phenomena in other parts of the nervous system of the affected side are present. When one of the wisdom-teeth, especially a lower one, becomes affected with total acute pulpitis, reflex pain in the ear, the larynx, the shoulder, and even in the lungs is frequently complained of. In the latter instance the patient is subject to great difficulty in breathing. If, however, the affected tooth is in the upper jaw, the reflex pain may affect the nerves of the supra- and infra-orbital region, the eye, and the nose. In exceptional cases the pain is located by the patient in teeth of the opposite jaw, although these may be quite sound. Should the pulp of a tooth affected with total acute pulpitis be left without treatment, the pain after five to eight days becomes less acute, and the inflammatory process gradually assumes a chronic character. If the carious cavity of an affected second or third molar tooth is situated in one of the approximal surfaces, it sometimes becomes difficult to tell which tooth causes the pain. In such an emergency either percussion, transillumination, or separation by wedges will assist the practitioner in making the diagnosis. After two or three days of pain from total acute pulpitis, the trouble is usually localized in the affected tooth.

Differential Diagnosis.—Total acute pulpitis may easily be confounded with other diseases of the pulp,—viz, chronic purulent pulpitis, and gangrene of the pulp. Chronic purulent pulpitis differs from total acute pulpitis principally in its reaction upon the pericementum. In the former disease the tooth becomes quite sensitive to pressure and percussion after the first day of inflammation, whereas in the latter the apparent elongation of the tooth and its sensitiveness to percussion and pressure are not marked in so high a degree, and do not appear till the third or fourth day after the beginning of the total acute pulpitis.

The subjective and objective phenomena of gangrene of the pulp are quite similar to those of total acute pulpitis. We are, therefore, unable to differentiate between these two diseases.

Prognosis.—It is not advisable to attempt to save a pulp that has become the seat of total inflammation. The only way to preserve the tooth permanently is completely to extirpate the pulp, and thoroughly to disinfect and fill the pulp-canal. When this has been successfully accomplished, the tooth may last as long as though it had a living pulp.

2. **Acute Purulent Pulpitis.**—The pathological description of

this disease is divided under the heads of *partial* and *total* pulpitis. Clinically, however, a differentiation is neither possible nor important. I shall therefore describe acute purulent pulpitis under one head.

Diagnosis.—When the carious dentine is carefully removed from the cavity of a tooth affected with acute purulent pulpitis, we always find the pulp exposed, at least at one of its horns. The exposed portion of the pulp does not lie close up to the dentinal wall of the pulp-chamber, but recedes somewhat from it at the orifice. As soon as the pulp-chamber is opened, pus oozes out, whereupon the patient is instantly relieved from pain. Pressure through a piece of cotton or a blunt instrument upon the exposed portion of the pulp, before the pulp-chamber has been opened, does not increase the pain instantly, but after a few seconds; and if then the pus be allowed to escape, the pain ceases altogether. Percussion upon a tooth affected with incipient acute purulent pulpitis produces no pain, although its sound may be slightly dull. After the second or third day the tooth will be sensitive to percussion, and its sound will be distinctly dull.

Subjective Phenomena.—In acute purulent pulpitis the pain is pulsatory, but seldom as severe as in the foregoing forms of pulpitis. The paroxysms of pain are protracted, usually from four to twelve hours, and as the disease proceeds the painless intervals are progressively shortened, until the pain becomes continuous. In those cases where the pulp is still covered with a layer of softened dentine, the tooth is extremely sensitive to heat, but the pain is relieved upon the application of cold. The pain in the affected tooth produced by the heat is due to the expansion of gases accompanying the pus in the closed pulp-chamber. As gases are greatly expanded by heat, the result is obvious. In some instances, and especially in weakly-constituted persons, acute purulent pulpitis is accompanied by an elevation in the temperature of the patient, which begins as soon as pus forms.

Differential Diagnosis.—Acute purulent pulpitis may be confounded with three other diseases of the pulp,—viz, *partial acute pulpitis*, *chronic purulent pulpitis*, and *gangrene of the pulp*. In partial acute pulpitis the pain is more intermittent, and when the carious portion is removed from the cavity of the affected tooth, the pulp almost protrudes, and if wounded will yield bright-red blood; while in acute purulent pulpitis the pulp is somewhat retracted at the exposed horn, is very sensitive to heat, and when the pulp-chamber is opened pus instead of blood oozes out. The principal difference between acute and chronic purulent pulpitis is that in the latter the pulp is exposed quite largely, or in several places, the pain is much less severe, and the tooth aches but little upon application of heat. Gangrene of the pulp also may be mistaken for acute purulent pulpitis, but when the pulp-chamber of a tooth affected with the former disease is opened we observe in it a grayish or brownish fluid, with the characteristic odor of gangrene.

The prognosis for pulps of teeth affected with acute purulent pulpitis is always unfavorable. In these instances the sooner the pulp is removed, and the pulp-canal disinfected and filled, the better. This, successfully accomplished, will usually save the tooth.

III. CHRONIC PULPITIS.

1. **Hyperplasia.**—*a.* PARTIAL.—Clinically considered, there are two varieties of partially hyperplastic pulps,—the myxofibrous and the sarcomatous. But as the latter belongs to the tumors, I shall consider it in the chapter on that subject.

Diagnosis.—Under the head of partial hyperplasia we will consider such pulps as are found in teeth largely decayed in their entire grinding-surface, and exposed at one or all of their horns. The pulps have grown out of the pulp-chamber, and their surface presents a lobulated appearance, of a crimson hue. These little tumors of the pulp vary in size from that of the head of a pin to that of a pea, or even more. They occur mostly in the molar teeth; sometimes they are seen in the bicuspids and cuspids, exceptionally in the incisors. This disease, when it affects the pulp of an upper molar, starts usually from the lingual root, while hyperplasia of the lower molars commonly originates in both roots. Pulps affected with partial hyperplasia are not very sensitive to mastication, nor to the touch of an instrument. Even a probe introduced along the wall of the pulp-chamber for a little distance produces no pain, though it will usually start a profuse hemorrhage. The hyperplastic portion is connected with the unchanged pulp within the pulp-chamber or the canals by means of a constricted stem or pedicle.

The subjective phenomena of partial hyperplasia are quite few, and beyond a sensation of uneasiness in the affected teeth no pain exists, unless pronounced thermal changes or mechanical injury affect the pulp.

Differential Diagnosis.—Partial hyperplasia of the pulps may sometimes be confounded with granuloma of the gums, or the pericementum which occasionally occurs when, besides the cavity in the grinding-surface, a tooth also contains a carious cavity in the neck under the gum communicating with the pulp-chamber. In these cases the gum or the pericementum may grow into the pulp-chamber and appear in the cavity on the grinding-surface of the tooth. Their vulnerability renders an examination difficult, and the best way to arrive at a correct diagnosis is to insert a piece of cotton saturated with carbolic acid as far into the pulp-chamber as possible, leaving it for about twenty-four hours. Then we are usually able to make the examination.

The prognosis for the preservation of the pulp is bad; but the tooth can be saved if the pulp be extirpated and the canals filled, which in partial hyperplastic conditions of the pulp is usually easy to accomplish.

b. TOTAL HYPERPLASIA.—*Diagnosis.*—This disease is more common in teeth whose pulps are largely exposed by caries, but is met with in some instances, where the pulp is still covered by softened dentine. Pressure upon the dentine in the vicinity of the pulp is not painful, except when foreign substances enter the pulp-chamber. When the softened dentine is removed from the carious cavity, and the pulp exposed, we are able to enter it for some distance with a fine instrument, and sometimes we even touch the periphery of the pulp without producing pain. But the pulp in this condition bleeds easily and profusely upon the slightest injury. The tooth is acutely sensitive to thermal changes, and an injection of hot or cold water into the cavity causes pain. The pain, however, does not start of a sudden, but gradually, lasting from one to ten minutes. As a rule, the tooth is somewhat loose, though not sensitive under pressure nor during mastication unless these irritate the pulp directly. Percussion upon the affected tooth is answered with a slight dullness in the sound, and also detects a tenderness, which proves that the chronic inflammation of the pulp has reacted upon the pericementum.

Subjective Phenomena.—In chronic hyperplasia of the pulps we rarely observe severe pain, unless the inflammatory process should enter an acute stage. The first warning the patient has of the trouble consists of an uneasy sensation, which he is usually able to localize in the affected tooth. This may continue from fifteen minutes to three or four hours, followed by absolutely painless intervals of a day, a week, or even of months. The paroxysms of pain are usually produced by irritating substances brought in contact with the exposed pulp, although in some cases constitutional derangements are apt to bring on a paroxysm of pain, oftentimes acute. Whenever the pulp of such a tooth becomes disturbed, either by constitutional or local irritants, the tooth begins to ache severely and exhibits all the phenomena of a total acute pulpitis, lasting from two to four days. When the patient suffers from such an acute attack, we usually observe reflex pains in other parts of the nervous system, similar to those experienced in total acute pulpitis, when produced by eburnification and ossification of the pulp. Usually after that the tooth is comfortable for several weeks or months. Every attempt at destroying, by means of arsenious acid, a pulp affected with total hyperplasia will result in an excruciatingly painful paroxysm, and in a failure to accomplish devitalization. The character of the pain in such an acute paroxysm is mostly dependent upon the area of the exposure of the pulp. In cases where the pulp is largely exposed and not covered by softened dentine, the pain will be considerably less than in cases where the exposure of the pulp is small, or the pulp is still covered by softened dentine.

Differential Diagnosis.—Three diseases of the pulp may be confounded with total hyperplasia of the pulp: *total acute pulpitis*, *gangrene of the pulp*, *eburnification* and *ossification* of the pulp. The principal difference between total acute pulpitis and total hyperplasia of the pulp is in the reaction produced upon the pericementum, which in the former instance is but slight; in the latter, quite noticeable. Another characteristic feature of hyperplastic pulps is their behavior upon the application of carbolic acid, campho-phenique, phenate of cocaine, aconite, etc., which in this disease never give ready relief when applied during an acute paroxysm of pain, whereas they act instantly in cases of total acute pulpitis. Gangrene of the pulp can be distinguished from its total hyperplasia, although the subjective and the objective symptoms of both diseases are similar. In the former, when the pulp-chamber is opened we observe the characteristic smell of gangrene, which never is present in total hyperplasia of the pulp. Quite different, however, is the case when the tooth is so sensitive that we are unable to open the pulp-chamber. In such an instance a correct differentiation between these two diseases cannot be made. Total hyperplasia of the pulp may also be confounded with eburnification and ossification of the pulp, the more so as most of the hyperplastic pulps in time partially degenerate into dentine and bone. Moreover, the degeneration into dentine and bone, as spoken of in the next chapter, principally occurs in teeth not affected by caries. Whether this exists or not can be ascertained by careful examination.

2. Chronic Purulent Pulpitis.—The morbid anatomy of chronic purulent pulpitis, like that of acute purulent pulpitis, admits of two forms of the disease under consideration. As it is of little importance to the practitioner whether a pulp is affected by partial, or by total chronic purulent pulpitis, I shall discuss the disease in one paragraph, especially since the term *total* purulent pulpitis, as usually applied, is a misnomer. So soon as all the pulp-tissue has been transformed into pus, there is no longer any pulpitis, but a pulp-chamber filled with pus instead. In the majority of instances, however, we still find remnants of pulp-tissue, as evidenced in the chapter on the morbid anatomy of pulpitis.

Diagnosis.—Chronic purulent pulpitis is found in teeth with large carious cavities, whereby the pulp has been exposed largely or in several places. The dentine covering the exposed portions of the pulp is always quite soft, and frequently such a deterioration extends over the greater portion of the pulp-chamber. This form of pulpitis is easily recognizable by the quantity of pus eliminated upon the opening of the pulp-chamber, in cases where this has remained covered by softened dentine. Usually but a few drops of pus appear, but in exceptional cases the pulp-chamber, on being opened, yields about a teaspoonful of pus or even more. In such instances there is present, additionally to the pulpitis under consideration, an acute or chronic purulent pericementitis. In general, however, in this disease, when the pulp-chamber is found open, most of the pus has already escaped, and upon examination we only find one or two drops of it in the pulp-chamber. A probe may be introduced into the pulp-chamber for some distance without producing either pain or hemorrhage. Indeed, when an instrument enters the pulp-chamber of the tooth, causing the evacuation of the pus, the patient is instantly relieved. Pressure upon the softened dentine in the vicinity of the pulp-chamber elicits no reaction, except in those rare cases where the pulp-chamber is still inclosed by softened dentine. A characteristic feature of this form of pulpitis is the presence of pericementitis, which in the earlier stages of chronic purulent pulpitis is acute. In those instances, on the contrary, in which the pulp-chamber has been largely perforated, and chronic purulent pulpitis has existed for four weeks or more, it is associated with chronic purulent pericementitis. Percussion as well as slight pressure upon the affected tooth will be quite painful, and the former will elicit the characteristic dull sound.

Subjective Phenomena.—In chronic purulent pulpitis, the patient complains of moderate throbbing and shooting pain in the affected tooth, which, owing to the inflammatory process set up in the pericementum, is quite sensitive upon mastication. When the perforation in the pulp-chamber is small, and most or all of the pus retained in the pulp-chamber, the tooth is extremely sensitive to heat, which, however, is not the case when the perforation of the pulp-chamber permits the evacuation of the pus. Usually, whenever pus is formed, the patient is attacked by a chill followed by more or less fever, the severity of which depends upon the quantity of pus accumulated in the pulp-chamber and the pericementum, as well as upon the constitutional peculiarities of the patient.

Differential Diagnosis.—Chronic purulent pulpitis may be confounded with four diseases,—viz, *acute purulent pulpitis*, *acute total pulpitis*, *gangrene of the pulp*, and *acute alveolar abscess*. Acute purulent pulpitis differs from the chronic form principally in the inflammatory reaction which the latter always produces, while in the former it is scarcely noticeable. Other characteristic features of chronic purulent pulpitis are the large extent of the carious cavities, and the quantity of pus eliminated upon opening the pulp-chamber; whereas in acute purulent pulpitis the pulp is, as a rule, exposed only at one of its horns, and but one or two drops of pus are seen at the perforation of the pulp-chamber. Total acute pulpitis differs from chronic purulent pulpitis principally in that when the pulp-chamber is opened blood oozes forth, and pressure in the vicinity of the pulp-chamber produces intense pain; whereas in chronic purulent pulpitis pus is present, and no pain is experienced upon pressure in the neighborhood of the pulp-chamber. In its latter stages chronic purulent pulpitis may easily be confounded with acute alveolar abscess, while in its beginning we always find traces of sensitive pulp-tissue in some parts of the pulp-chamber or root-canal.

Prognosis.—In chronic purulent pulpitis the death of the pulp of the tooth is inevitable, and the earlier the pulp be extirpated the better is the chance of preventing the formation of an acute alveolar abscess. When pericementitis has but slightly developed, and great care is exercised in the removal of the pulp, by absolutely *aseptic* instruments, the canals after a thorough preparation and disinfection may at once be filled and no trouble will follow, provided micro-organisms have not already entered the pericementum during the process of pulpitis. If, however, the pericementitis has progressed to the stage of tenderness or fluctuation above the end of the root, the pulp-canal cannot be filled at once, though by skillful treatment the preservation of the tooth is possible.

IV. GANGRENE OF THE PULP.

a. **Moist.**—This disease is most common in carious teeth, the pulp-chambers of which are still covered with softened dentine. The extent of the carious cavities in the teeth affected with moist gangrene seems to have no influence upon the infection of the pulp. In some instances we meet with carious cavities representing an almost straight tube-like canal, not much larger in diameter than a stout nerve-broach: in others we see almost the whole crown of the tooth lost, before the pulp is attacked by moist gangrene. This process usually starts at one of the horns of the pulp, rapidly destroying it in the direction of the root. For this reason an examination by means of a probe, when handled carefully, is painless to the patient, even in the first stages of moist gangrene. At the same time the examination of the pulp-chamber of such a tooth will leave no doubt as to the correctness of the diagnosis, because the instrument employed will inevitably be tainted with the characteristic odor of gangrene. In perforating the pulp-chamber of a tooth, the pulp of which we suspect to be gangrenous, care must be exercised not to exert too much pressure, as in the beginning of the process only the horn is destroyed, and the instrument might enter the yet unaffected pulp-tissue, an exceedingly painful accident. In many instances, however, we are enabled to pass the broach almost to the apex of the root without producing pain. In these cases, when an infection of the pericementum has occurred, the gangrenous process has advanced nearly to the apex of the root; or it will do so as soon as a broach reaches the apical foramen of the roots of the tooth, unless the pulp-canal had been previously made aseptic. It is therefore advisable during the examination of a pulp-canal *never to enter the root-canals of a tooth* by instruments. One of the most characteristic signs of both moist and dry gangrene is the discoloration of the tooth, especially marked in the incisors and cuspids. Before other instruments are employed, transillumination, either by reflected or electric light, will greatly assist in making the diagnosis. The color of such teeth depends upon the acuteness and the stage of the process. At the beginning of gangrene, when only a part of the coronal portion of the pulp has been destroyed, there is seldom any discoloration visible. In further stages, however, when most of the coronal portion of the pulp has been devitalized, the tooth changes its color, at first to a slightly grayish-blue, gradually becoming darker, until it assumes a dirty brownish or even blackish shade. In some instances, when in the process of acute pulpitis a blood-vessel had ruptured, and the pulp dies, the tooth rapidly changes its color, at first to a light pink, and after one or two weeks to a dark brown. The discoloration in all instances, however, will be slight, or even not noticeable at all, when the pulp has been removed before it is wholly destroyed by the gangrenous process.

The subjective phenomena of moist gangrene are quite severe intermittent pains, which in the first stages last from a few minutes to half an hour. In the later stages, however, a paroxysm may last over one hour. The pain mostly arises spontaneously, and does not seem to be started nor aggravated by thermal changes. A tooth affected with moist gangrene is never quite free from pain. Even between the paroxysms the patient complains of an uneasy feeling or slight pain, that increases in severity as the gangrene advances. In the latter stages of the process the tooth, up to that time comfortable, begins to get sore in mastication, and becomes elongated in its socket,—a characteristic sign of the infection of the pericementum and its inflammation.

Differential Diagnosis.—Moist gangrene of the pulp may be confounded with the majority of the diseases of the pulp, but especially with *acute partial*, *acute total*, *acute purulent*, and *chronic purulent pulpitis.* The principal characteristic symptoms of gangrene of the pulp are usually a sensitiveness to pressure upon the softened dentine of the pulp, and, when the instrument enters the pulp-chamber, the gangrenous odor.

Prognosis.—In the first stages of moist gangrene of the pulp we may, in some instances, succeed in amputating the coronal portion of the pulp, and thus save the pulp-stumps; but this success must be regarded as exceptional. The best procedure to preserve the tooth is the complete extirpation of the pulp and filling of the root-canals as soon as the diagnosis of gangrene of the pulp has been made. The earlier this is accomplished the better will be the color of the tooth, and the less is the probability of a succeeding pericementitis.

b. **Dry Gangrene.**—*Diagnosis.*—While moist gangrene is of frequent occurrence, dry gangrene of the pulp is not so often observed. Dry gangrene of the pulp usually occurs in teeth the crowns of which have not been attacked by deep-seated caries. The teeth usually show a grayish-blue discoloration, and often this has been noticed for years before such teeth have given pain or discomfort. Percussion upon a tooth affected with dry gangrene will produce no pain, but often a slightly dull sound.

Subjective Phenomena.—Besides the discoloration of the tooth, there is no symptom to inform the patient of the existence of the disease.

Differential Diagnosis.—Dry gangrene may, perhaps, be confounded with moist gangrene of the pulp, although in the latter disease the patient has suffered more or less pain before the tooth became discolored, and when the pulp-chamber is opened the characteristic smell is present. Teeth affected by dry gangrene are not decayed, and when the pulp-chamber is opened we find a grayish-white filamentous substance, perfectly dry, and with no perceptible odor. Some teeth affected with dry gangrene remain so perfect in color that a differentiation between them and the teeth with living pulps is almost impossible. In such instances an application of the chloride-of-methyl spray ought to be made as near to the neck of the tooth as possible, with the precaution to adjust the rubber-dam on the tooth to be sprayed. If the tooth does not react upon the spray, the pulp is dead; whereas a living pulp will ache considerably upon the use of the chloride-of-methyl spray.

The prognosis of a tooth affected with dry gangrene is always favorable, and when the tooth is bleached by pyrozone, the discoloration usually does not return.

CHAPTER XXXV.

MORBID ANATOMY OF PULPITIS.

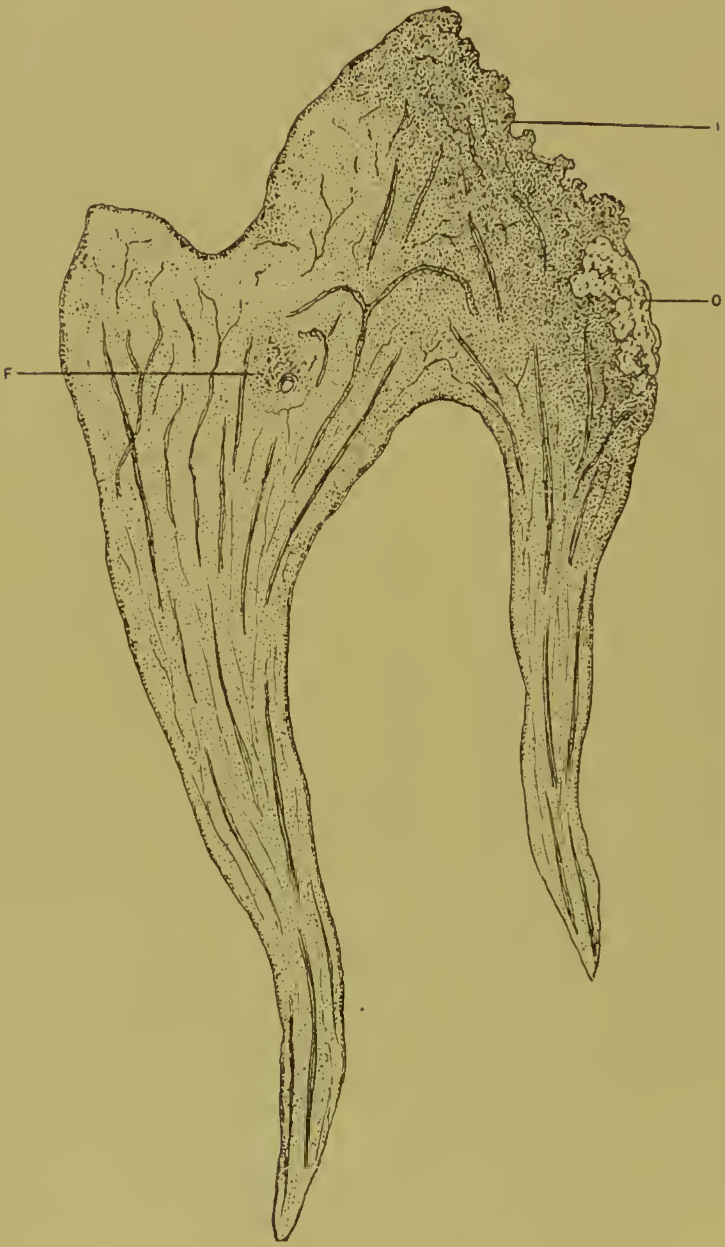
I. Acute Pulpitis.—In accordance with the classification of pulpitis laid down in the previous chapter, I propose to consider first the acute non-purulent form.

a. Acute Non-Purulent Pulpitis.—This may be either partial or total, the former being far more common than the latter. Partial pulpitis is usually found in the crown portion, starting from its surface and due to an irritation brought to bear upon the pulp-tissue, commonly by the approach of a carious process. It is much less frequently met with in the root-portion of the pulp, having for its origin an irritation transferred from pericementitis.

Acute superficial pulpitis is illustrated with a low power in Fig. 210. In this example only the surface of one horn of the crown portion has been attacked. We may infer that this same horn had been previously attacked by a slight plastic inflammation which led to fibrous hyperplasia, and a deposition of lime-salts in the shape of osteoid tissue (*O*). The later acute attack has, however, led to an acute inflammation even of the fibrous portion. A peculiar feature observable in this pulp, and one with which we frequently meet in pulpitis, is the general dissemination of the inflammatory foci (*F*), which are usually established around larger blood-vessels.

Specimens of this type, if carefully preserved in dilute chromic-acid solution and sliced by the microtome, afford excellent opportunity for the study of the process of pulpitis, with medium and high powers of the microscope. (See Fig. 211.) The spot selected for illustration exhibits three grades of acute pulpitis, passing from a quite intensely-inflamed region to a slightly-inflamed one. In the former, the myxomatous structure of the pulp-tissue is nearly destroyed, and in its stead we see a large number of lumps of living matter, mostly clustered, in varying

Fig. 210.

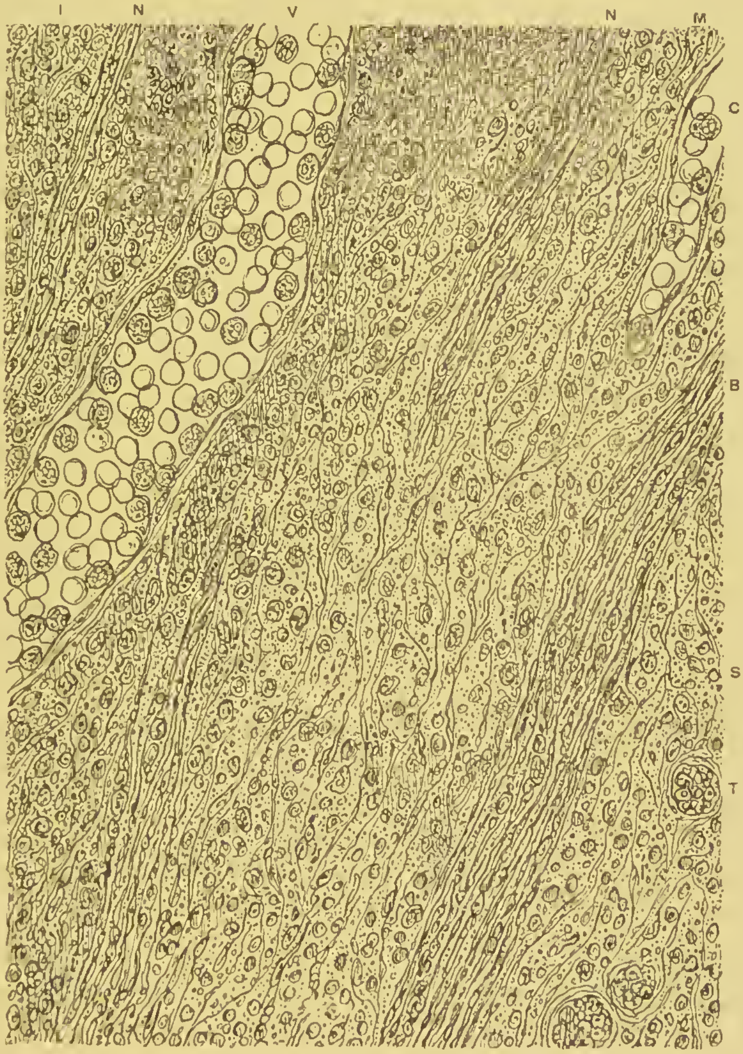


Acute Pulpitis in the Coronal Portion.

I, intensely-inflamed horn; *O*, osteoid tissue; *F*, apparently isolated inflammatory focus. Magnified 10 diameters.

phases of development, from a minute granule of compact living matter to a distinctly outlined, coarsely-granular protoplasmic body. We trace the development of such lumps, not only from previous lymph-corpuscles by a process of splitting or division, but also from the trabeculæ of the myxomatous network and from the protoplasm or myxomatous substance filling the meshes of the myxomatous net-work. Since the development of these so-called inflammatory corpuscles is so easily

FIG. 211.

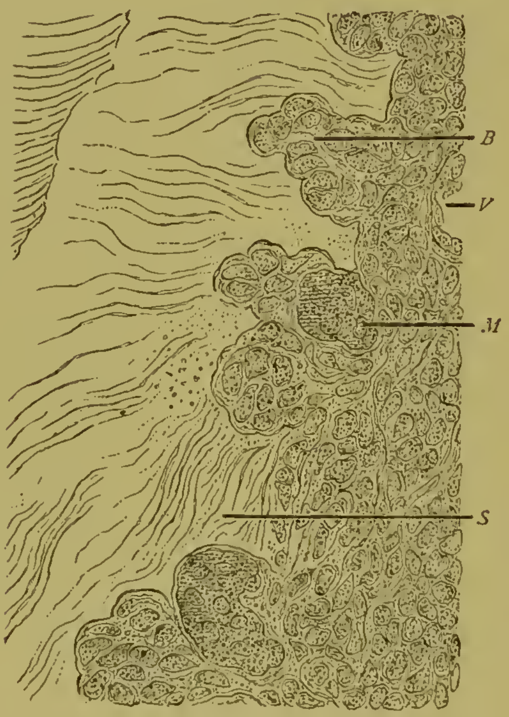


ACUTE PULPITIS.

I, intensely-inflamed portion; *M*, moderately-inflamed portion; *S*, slightly-inflamed portion; *N*, *N*, small bundles of medullated nerves, intensely inflamed; *B*, large bundle of medullated nerves, slightly inflamed; *T*, nerve-bundle in transverse section; *V*, vein, engorged with red and colorless blood-corpuscles; *C*, capillary, engorged and widened. Magnified 500 diameters.

traceable, as originating from all the components of the pulp-tissue, we again are placed in position to emphatically deny the emigration of leucocytes according to J. Cohnheim's theory. True it is that the capillaries and small veins within the inflammatory focus are engorged with red and colorless blood-corpuscles, the latter being accumulated mainly along the walls of the vessels. True it is, also, that the leucocytes creep through the walls of the capillaries and small veins; but this occurs in the preliminary stage of inflammation in hyperæmia, and is by no means an essential feature of inflammation.

FIG. 212.



ACUTE PULPITIS.

S, secondary dentine; *B*, bay-like excavations filled with medullary or inflammatory corpuscles; *V*, transverse section of a blood-vessel; *M*, multinuclear body. Magnified 300 diameters.

The nerve-bundles break up into inflammatory corpuscles. First the perineurium, next the myelin investment, then after the disappearance of the myelin, lastly the axis-cylinders themselves take part in the production of inflammatory corpuscles. This transformation easily explains the severe pains caused by an acute though only superficial pulpitis.

Should an acute inflammation start in a pulp around which secondary dentine had been formed, the latter would likewise be affected, its lime-salts being dissolved out in bays similar to those seen in inflamed cementum and bone-tissue, filled with multinuclear protoplasmic bodies or inflammatory corpuscles. (See Fig. 212.)

There are two ways of explaining this feature,—*i.e.*, the inflamed tissue itself may have caused the liquefaction of the basis-substance of the secondary dentine and grown into the bays thus produced; or the living matter belonging to the secondary dentine may have grown up to inflammatory corpuscles and so-called giant-cells. The latter view seems to me to be the most probable.

All the tissue-changes described become less pronounced the nearer we approach the healthy portion of the pulp, and frequently the border-line between the inflamed and normal portion is quite abrupt.

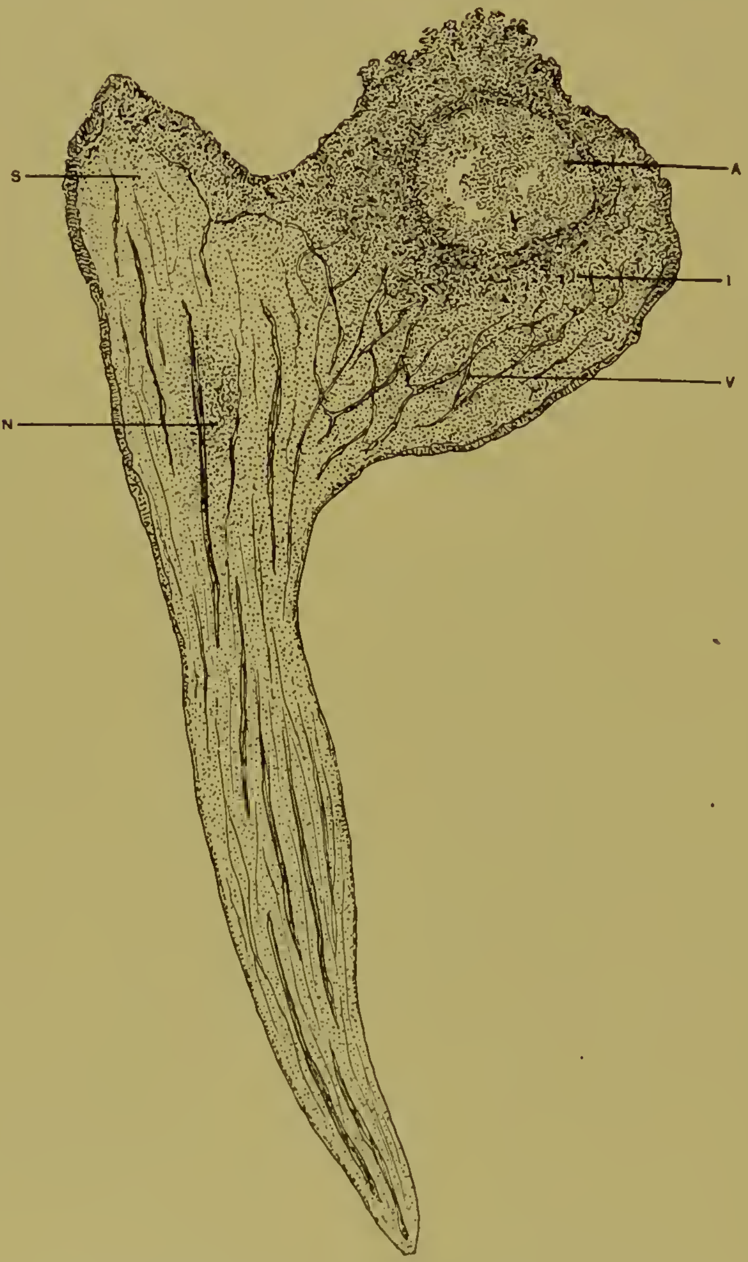
Among recent authors, Arkövy and Rothmann describe a septic superficial pulpitis due to an invasion of the pulp by streptococci. Rothmann depicts this alleged form of pulpitis; but in his figure only normal pulp-tissue is seen, together with a few streptococci. Whether or not such a partial septic pulpitis exists I am unable to say from my own observation, and I fully concur with A. Witzel in the view that in such cases we have no right to speak of pulpitis, but only of irritation of the pulp.

Should the entire pulp be affected, which is very rare, it will be found crowded with inflammatory corpuscles. The outcome of this form of pulpitis seems to be invariably suppuration, or, through the complete destruction of all blood-vessels, gangrene of the pulp.

b. Purulent Pulpitis.—So long as the inflammatory corpuscles remain interconnected, inflammation of the pulp is always nonpurulent. So soon, on the contrary, as the connections of the corpuscles are torn, we have as a result the appearance of pus-corpuscles. Again, the formation of pus may be limited to one horn of the crown, or may affect all parts of the pulp. In the former instance, the trouble is known as *abscess of the pulp;* in the latter as *suppuration of the pulp.*

An instance of acutely-formed abscess is illustrated in Fig. 213. Luckily, the pus-corpuscles have remained *in situ* in this specimen, perhaps owing to its being imbedded in celloidin. A well-defined border line is seen between the inflamed and the suppurating portions of the pulp. The former takes the stain of ammoniacal carmin, the latter does not. In the vicinity of the abscess most of the blood-vessels are obliterated by being transformed into longitudinal clusters of inflammatory corpuscles. It is reasonable to assume that the disintegration of the inflamed

Fig. 213.



Acute Suppurative Pulpitis in the Coronal Portion.

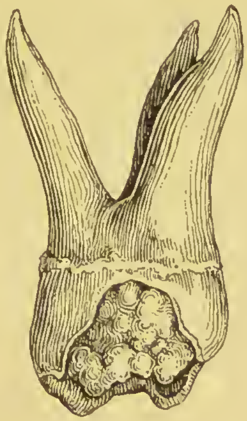
I, intensely-inflamed horn; *A*, abscess; *V*, blood-vessels engorged with blood; *S*, superficially-inflamed horn; *N*, nest of inflammation. Magnified 10 diameters.

tissue, notwithstanding the presence of enormous numbers of staphylococci, is due to the destruction of the blood-vessels.

Should this disintegration take place throughout the entire pulp, suppuration will follow everywhere, and in such a case the whole pulp-chamber will be transformed into an abscess-cavity. Such a termination of *acute* purulent pulpitis seems to be exceedingly rare. Far more commonly, the coronal portion, or one or several root portions, are transformed into pus, while one or more root portions remain in the stage of acute pulpitis without being destroyed by suppuration.

II. Chronic Pulpitis.—Modern writers claim that chronic pulpitis is not inevitably the outcome of primary acute pulpitis. This holds good in my experience for a certain number of cases. Unquestionably, however, the outcome of a slight acute process must be the form which I propose to term hyperplasia. In the light of late researches we must admit that any particular form of tissue, before its transmutation into another form, will have to be reduced to an intermediate state of indifference, its embryonal or medullary condition. Acute pulpitis furnishes such an intermediate stage of indifference. Since the term inflammatory corpuscles is synonymous with that of embryonal or medullary corpuscles, the result of the production of a new tissue is termed hyperplasia. Such hyperplasia may yield a tissue kindred to the originally inflamed one, the result being a new formation of myxomatous tissue; in other instances, the result will be the transmutation of the myxomatous lymph-tissue into fibrous connective tissue.

Fig. 214.

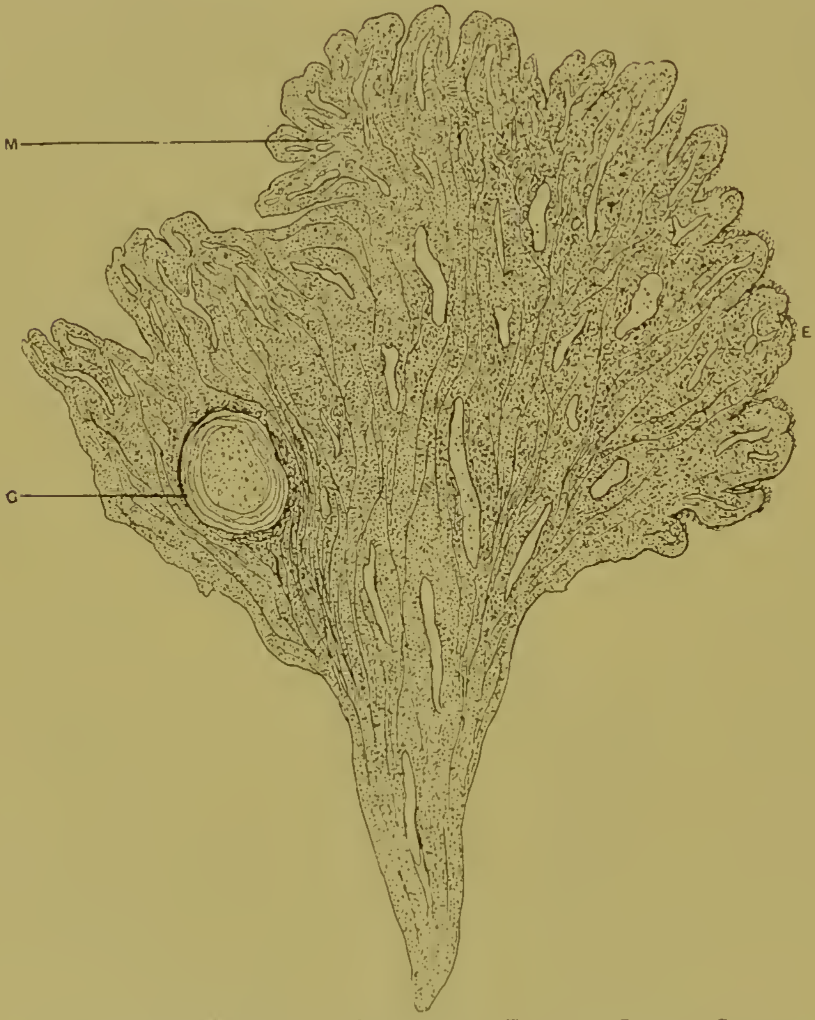


Left Upper Molar with Partial Hyperplasia of the Pulp.

Magnified 2 diameters.

In many instances, an exposed and consequently inflamed pulp at the bottom of a large carious cavity, instead of perish-ing by suppuration, produces so-called "*proud flesh*," known to the pathologist as *granulations*. (See Fig. 214.) Such granulations are often pediculated, starting from the narrow root portion and freely expanding over the open cavity. They are known to sprout out wherever a wound on the surface of the body heals by suppuration. Similarly the exposed pulp produces crimson-red, slightly lobulated granulations, with a continuous though slight discharge of pus.

FIG. 215.



HYPERPLASTIC MYXOMATOUS PULP, WHICH FILLED A CARIOUS CAVITY.

M, lobules made up of papillæ of a myxomatous structure, rich in capillary and venous blood-vessels; *G*, calcareous globule; *E*, epithelial cover of papillæ. Magnified 10 diameters.

Under the microscope the granulation-tissue is seen with low powers to consist of myxomatous connective tissue freely supplied with blood-vessels, but lacking nerves. (See Fig. 215.) The size to which such an outgrowth may expand is almost unlimited, a circumstance due to the continuous outgrowth of myxomatous tissue with an equally continuous new formation of capillary blood-vessels by means of sprouts of the capillary blood-vessels, which are at first solid, and afterward vacuoled and hollowed out. The layer of the myxomatous tissue nearest to the surface is broken down into protoplasm, and furnishes the source of suppuration. (L. Heitzmann.)

There can be no doubt as to the origin of the peculiar formation illustrated in Fig. 215 from previous pulp-tissue, since a calcareous globule is present which obviously could have been formed only in a pulp.

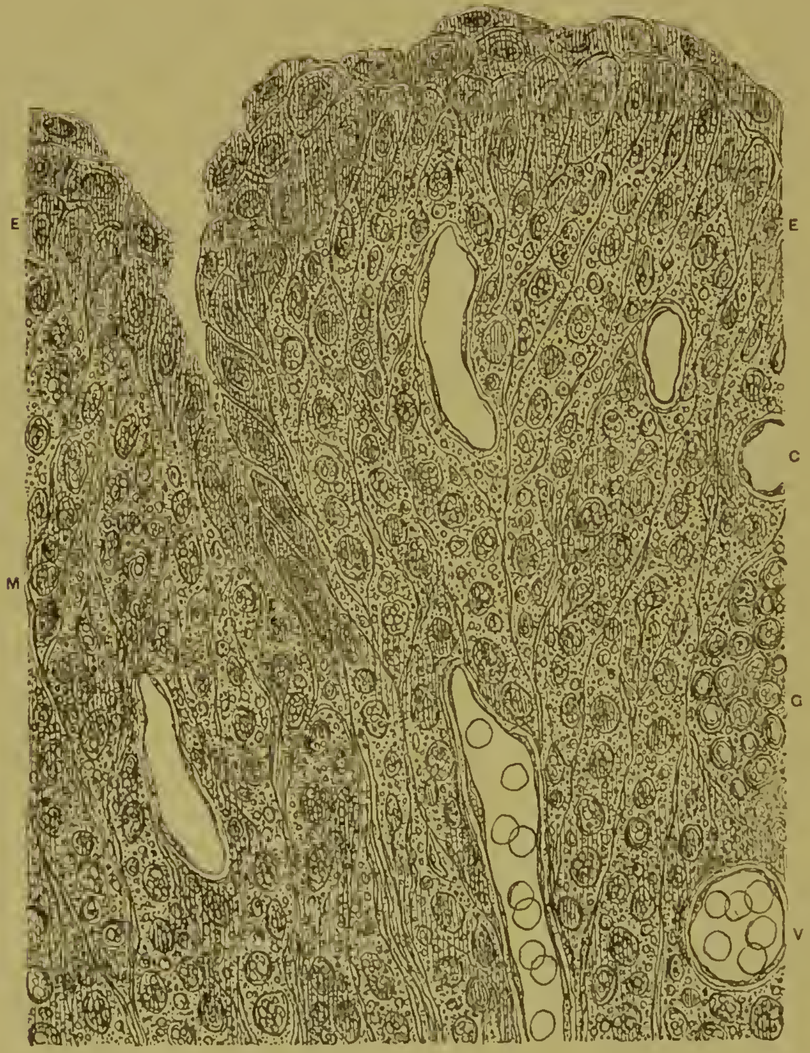
Not infrequently the granuloma filling a carious cavity does not suppurate on its surface. In such a case, the surface is found covered with an incompletely stratified epithelium, to the presence of which Arkövy first drew attention. Nay, it may occur that a portion of the granuloma yields pus, while another portion is covered with epithelium, as is seen in Fig. 215.

Considerable interest attaches to the covering epithelium found at the surface of a tissue-formation, sprung from pulp-tissue which lacks epithelia altogether. (See Fig. 216.) There are two possibilities for the explanation of this peculiar fact. Those who adhere to the theory of the mesoblastic origin of connective tissue will deny the possibility of an epiblastic tissue, such as epithelium is, taking its origin from connective tissue. For these investigators there exists but one possibility,—viz, a transplantation of epithelia from any portion of the oral mucosa to the surface of the granuloma. Arkövy himself takes this view. Those who admit the possibility of an interchange of tissues of mesoblastic and epiblastic origin, as A. Kölliker did in previous years, will also concede that a transformation of connective tissue into epithelia may occur. I myself have strongly advocated the idea of the change of the epithelium of the original enamel-cord into myxomatous connective tissue of the enamel-organ. On the other hand, I cannot object to the view that connective tissue may be changed into epithelia. When we closely observe the row of columnar epithelia at the surface of a granuloma of the pulp, with medium powers of the microscope, we are struck with the elongated feet of a majority of these bodies, blending with the fibers that constitute the reticulum of the myxomatous granulation-tissue. (See Fig. 216.)

The final answer to the question under consideration has, however, not as yet been reached.

Far more frequently the outcome of pulpitis is the production of dense fibrous connective tissue. (See Fig. 217.) This tissue-change may involve either the entire pulp, or it may be confined to a part, not infrequently even to a small superficial portion. A feature of fibrous pulps is that they easily lead to the production of bone-tissue to a varying extent. Indeed, I have never met with spiculæ of bone in pulps which were not fibrous.

FIG. 216.

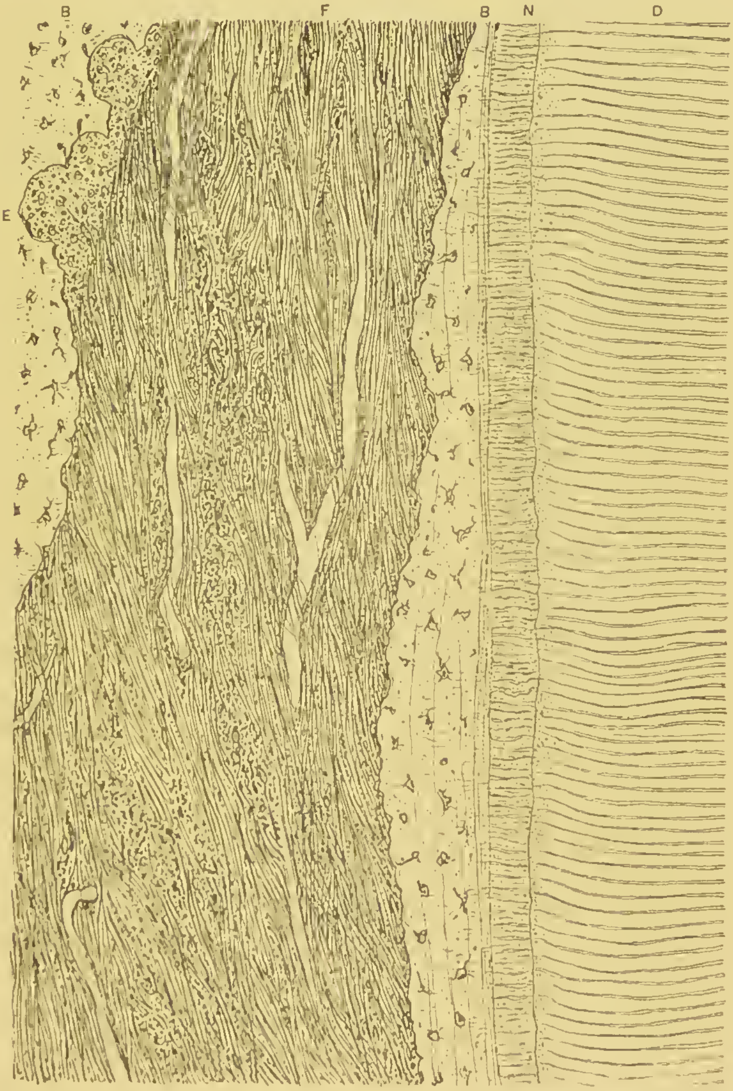


HYPERPLASTIC MYXOMATOUS PULP.

M, myxomatous granulation-tissue; *G*, cluster of small homogeneous corpuscles; *C*, capillary blood-vessel in transverse section; *V*, vein in transverse section; *E*, *E*, rows of irregular columnar epithelia, overlapped by cuboidal epithelia. Magnified 500 diameters.

If the fibrous tissue-change involves only a peripheral portion of the pulp, the new formation of bone will take place along the wall of the pulp-chamber, as in the case illustrated. Exceptionally, instead of bone, a tissue allied to it—*i.e.*, osteoid tissue—will make its appearance. (See Fig. 218.) This is the only instance where I have seen such osteoid tissue, which as to structure is evidently between calcification and ossification.

Fig. 217.

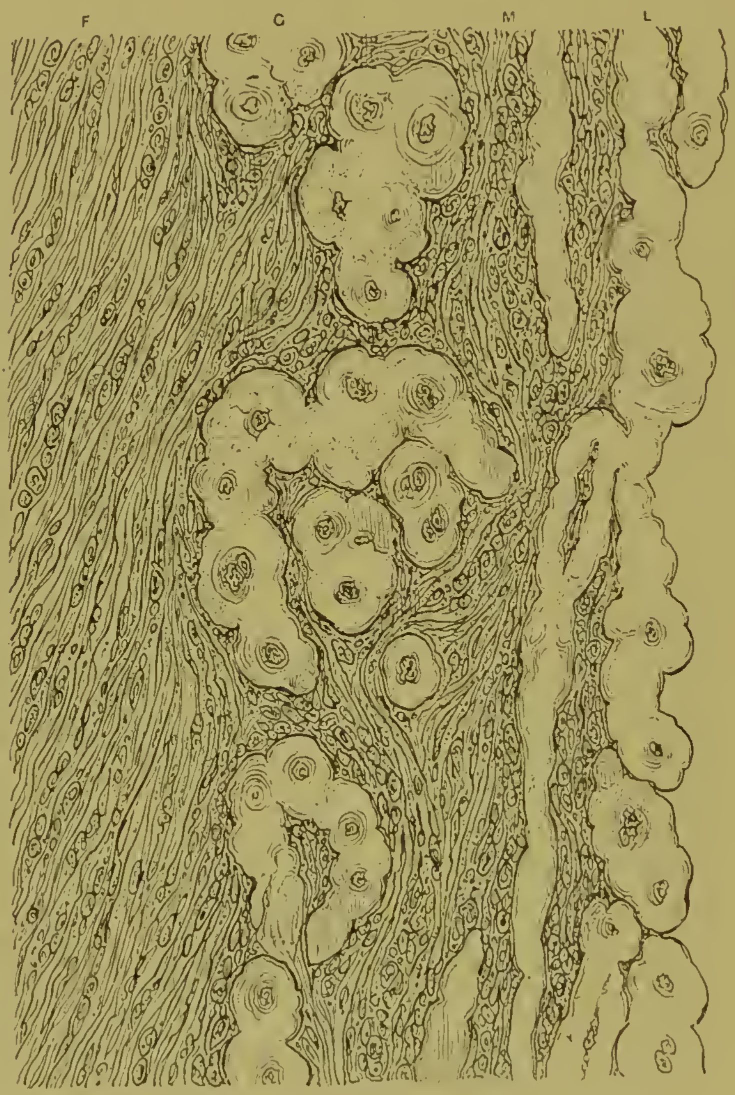


Fibrous Root Portion of Pulp with Ossification along the Dentinal Wall.

D, primary dentine; *N*, neck-like formation of bone-tissue; *B*, *B*, faintly lamellated bone-tissue; *F*, fibrous pulp with scanty blood-vessels, bundles interlacing; *E*, bay-like excavations in the bone-tissue. Magnified 200 diameters.

Should pulpitis again attack a fibrous pulp, the latter will be reduced to medullary tissue, and we shall see bay-like excavations corroding the periphery of calcified masses, or of newly-formed spiculæ of bone-tissue, the excavations being filled with multinuclear protoplasmic bodies. In the transmutation of myxomatous lymph-tissue into fibrous connective tissue the nerves seem to participate actively in the tissue-changes, which would explain the fact that fibrous pulps, or fibrous portions of the pulp, lack nerves altogether.

Fig. 218.

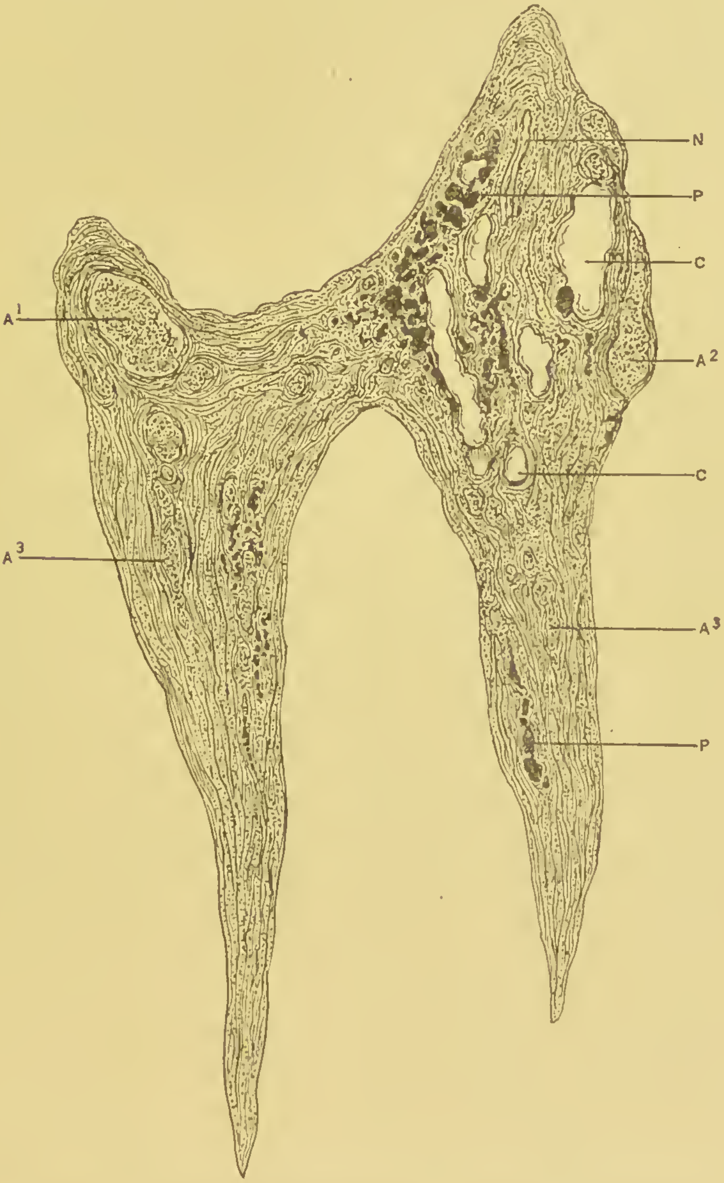


Osteoid Formations in the Pulp. (From Fig. 210.)

L, ledges of calcareous deposits along the border of the pulp; *G*, globular calcareous territories with central protoplasmic bodies; *M*, fibrous connective tissue crowded with medullary corpuscles; *F*, fibrous connective tissue the result of chronic plastic pulpitis. Magnified 500 diameters.

Chronic Purulent Pulpitis.—This, again, may appear in two forms,—partial and total suppuration. A chronic abscess is not infrequently found in the coronal portion of the pulp. It is, of course, invariably the outcome of an acute abscess.

FIG. 219.

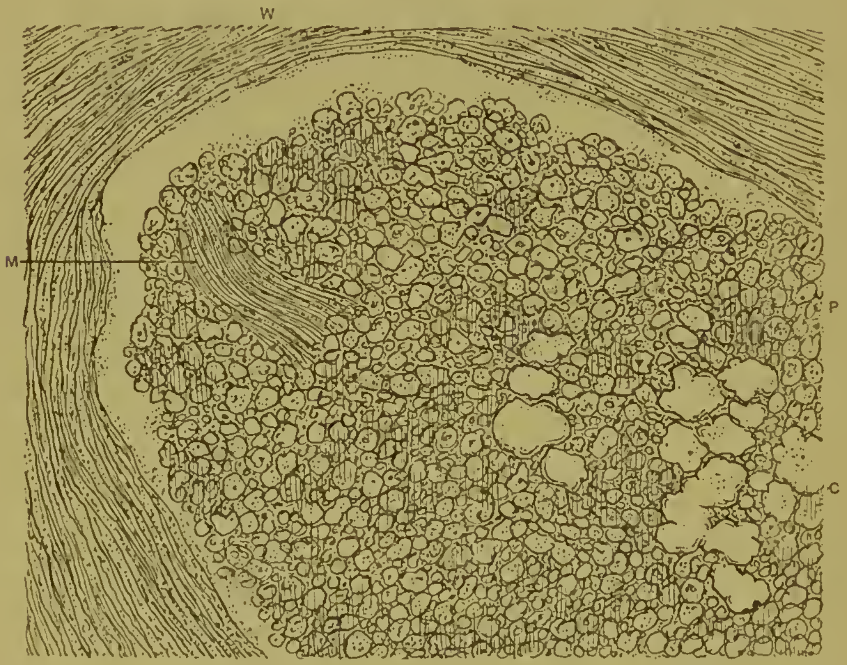


CHRONIC SUPPURATIVE PULPITIS TERMINATING IN CALCIFICATION OF THE PUS AND ATROPHY OF THE PULP.

A^1, larger abscess, filled with calcified pus; *A*^{2}, abscess at the periphery of the pulp; *A*^{3}, *A*^{3}, small longitudinal abscesses, all calcified; *N*, calcified nerve-bundle: *C*, *C*, calcareous depositions in the fibrous pulp-tissue; *P*, *P*, pigment clusters from previous hemorrhage. Magnified 10 diameters.

While in the latter form there is no distinct boundary-line at the border of the diseased territory, when the abscess has persisted for some length of time it becomes encapsulated by a layer of newly-formed fibrous connective tissue, the so-called "*membrana pyogena*" of older writers. Then the boundary-line is conspicuous, especially when the pus crumbles away in the process of section-cutting. As soon as the abscess has become chronic, the pus-corpuscles undergo fatty degeneration, the same as the contents of all chronic abscesses in the body. Still later the fatty pus becomes the seat of a deposition of lime-salts, and thus it is rendered harmless, since all micro-organisms are destroyed by this process. (See Fig. 220.)

FIG. 220.



SEGMENT OF ABSCESS OF PULP, HOLDING CALCIFIED PUS. (From Fig. 219.)

W, wall of abscess crowded with micro-organisms; *P*, calcified pus-corpuscles; *C*, calcareous masses; *M*, bundle of micro-organisms. Magnified 500 diameters.

Chronic total purulent pulpitis is, according to recent researches (Arkövy and Rothmann), a process not necessarily depending upon a preliminary stage of acute suppuration; just as in the case of acute total purulent pulpitis the chronic form commonly affects only parts of the coronal and root portions of the pulp, other portions almost always escaping destruction and remaining alive. (See Fig. 219.) In this figure we observe a large number of purulent foci of greatly varying size scattered throughout the entire substance of the pulp-tissue. The remainder of the living pulp-tissue has become fibrous, erecting walls around each abscess. As these are crowded with micro-organisms, it is probable that, with each newly-applied irritation, the micro-organisms induce suppuration again, and so a successive production of abscesses may go on almost indefinitely. The fibrous portions of the pulp may cause either a new growth of bone-tissue or the appearance of calcareous globules, as in the case illustrated. A fresh attack of purulent inflammation always leads to a partial dissolution of the lime-salts and the appearance of the bay-like excavations at the borders of both calcified and ossified tissues. Since, as stated before, change of the pulp to a fibrous tissue leads to a destruction of the nerve-bundles, it is reasonable to assume that chronic suppuration of the pulp is not accompanied with as much pain as is the acute.

If we examine the contents of a chronic abscess of the pulp, we invariably find the pus-corpuscles in a state of fatty degeneration,—*i.e.*, crowded with fat-granules. Occasionally the contents of a chronic abscess are pus-corpuscles in a high degree of calcification, owing to the deposition of lime-salts. (See Fig. 220.) This process renders each pus-corpuscle a glossy, indistinctly-granular and irregularly-contoured body, glued to its neighbors and intermixed with larger caked calcareous masses and groups of inert micro-organisms. The calcareous metamorphosis of pus explains why, in sections of pulps affected with chronic purulent pulpitis, the contents of the abscesses remain *in situ*.

III. Gangrene of the Pulp.—This process is invariably the outcome of acute pulpitis, when certain micro-organisms, as the Streptococcus septicus, obtain access to the inflamed pulp. In most cases of gangrene the pulp is transformed, in a short space of time, into a dark grayish-brown, pulpy, and fœtid mass, almost diffluent, not offering any reason for its preservation. The fœtid odor is due to the production of the gases of putrefaction. It has been asserted that the accumulation of such gases in the pulp-chamber has, by their expansion, led to a bursting of the crown of the tooth, the explosion being accompanied by a report resembling that of a pistol-shot. No certain data about such an accident have ever been recorded.

By an almost total stopping up of the caliber of the afferent artery, as, for instance, by an embolus, death of the pulp-tissue may ensue in the shape of so-called *dry gangrene*. In this process, the pulp, so far as my own experience teaches, is transformed into a grayish-white, dry mass, devoid of odor, mummification of the pulp-tissue, with an imperfect preservation of its constituent elements. To this process I shall devote a separate chapter, dwelling upon artificial mummification or coagulation-necrosis of the pulp-tissue.

CHAPTER XXXVI.

DEGENERATIONS AND ATROPHIES OF THE PULP.

I PLACE the above diseases of the pulp in a separate chapter, because these retrogressive tissue-changes are by no means always the outcome of pulpitis. Having examined a large number of pulps containing so-called pulp-stones, I can say that these are, as a rule, the result of irritation, but not of inflammation. True it is that they are frequently the cause of pulpitis.

a. **Calcification.**—Calcification occurs in two forms, *i.e.*, within the basis-substance of the myxomatous connective tissue, and in the nerves and blood-vessels.

Calcification of the basis-substance of the myxomatous connective tissue is of quite frequent occurrence, and seems to be more common in the pulps of teeth which have stood in crowded dental arches, the wisdom-teeth being especially prone to it. The age of the patient apparently does not influence calcifications of the pulp, as the writer has found them in the pulps of teeth of quite young, as well as old people. From external appearances, or subjective phenomena, we are unable to diagnose this form of calcification of the pulp, as it never causes trouble. The aspects are quite different, however, when calcifications occur in the blood-vessels or nerves of the pulp.

Diagnosis.—The latter form of calcification occurs only in teeth affected with chronic marginal pericementitis which has existed more than one year. The gums in the vicinity of the inflamed pericementum during a paroxysm of pain in the pulp appear acutely inflamed, and are somewhat sensitive to pressure. The tooth is raised from its socket, slightly loose, and sensitive to percussion and pressure. The characteristic features of this painful disease are, that the tooth *is of a normal color*, and extremely sensitive to thermal changes, especially cold. *The subjective phenomena* of calcifications of the blood-vessels and nerves of the pulp are characterized in the beginning of the process by slight intermittent pain. The process commences with acute marginal pericementitis, a so-called *blind abscess*, which after becoming chronic gradually affects the pulp of the tooth. The pain in the pulp usually begins two or three months after the first appearance of the pericementitis, in paroxysms, lasting at first a few hours, but in later stages they may continue for four days or even more. Such paroxysms of pain are usually induced by a depressed state of the general health. When the pain is over, the tooth continues to feel sore for two or three days, though usually the pain does not recur for a month or two. With every renewal of the attack, however, the pain becomes more severe and the paroxysms last longer. When such a tooth contains a cavity, or a gutta-percha filling, which is situated near the pulp-chamber, we may be able to relieve the patient from the terrible suffering which the disease produces in pronounced stages.

Differential Diagnosis.—Calcifications of the blood-vessels and nerves of the pulp may be confounded with an acute apical alveolar abscess, although in the latter instance the tooth is usually discolored and not sensitive to thermal changes. In this respect, a characteristic feature of teeth affected with calcifications of the blood-vessels and nerves of the pulp is the supersensitiveness of the dentine to the bur.

Prognosis.—Teeth whose pulps are affected by a calcification of the blood-vessels and nerves are usually lost, unless the pulp can be extirpated, which is barely possible in the advanced stages of this process, on account of the great sensitiveness of both the pulp and the dentine.

b. **Eburnification and Ossification of the Pulp.**—On account of the obscurity of their diagnosis, these disturbances of the pulp cause great trouble. The writer has met with patients who for months or even years have suffered intensely from what was supposed to be neuralgia of the face, arms, and the chest, the trouble subsequently localizing itself in the pulp of a tooth, and the pains ceasing instantly and never returning after the extirpation of the affected pulp. In order to emphasize the importance of this subject, I will briefly relate three characteristic cases met with in my practice.

I. For Miss S., aged fourteen years, I filled, on November 25, 1872, the second lower molar with amalgam. The cavity was situated on the buccal, near the mesial surface, and was rather extensive. The tooth, after the filling had been inserted, remained sensitive to thermal changes for a long time, but otherwise gave no trouble. In December, 1879, the tooth became decayed on its mesial surface, but in trying to prepare this cavity I found the dentine so extremely sensitive that the patient, being at the time in bad health, would not submit to it. June 3, 1880, I saw the tooth again, when the decay had reached the pulp-cavity. It had never given very much trouble, except when food, during mastication, was pressed into the cavity. I found the dentine sensitive as before, and concluded, therefore, to devitalize the coronal portion of the pulp, and made an application of arsenious acid. The next day, when the patient entered my office, she told me she felt better than for many months. When I removed the dressings and examined the state of the pulp, I found a large so-called "pulp-stone" lying toward the amalgam filling. The patient, since that time, has had no more neuralgia, has grown quite strong and vigorous, and the molar, with the coronal portion of the pulp amputated, does good service, and has not given any further trouble.

II. On September 3, 1881, Mrs. R., aged twenty-two, came to me with excruciating pain in the left upper lateral, containing a large gold filling in its mesial surface which had been inserted several years previously. About a year before the patient first noticed lameness of the left arm, which, after some weeks, had terminated in more or less constant neuralgia, affecting, at times, the entire left side of the body; but no pain was observed in this tooth previous to the 1st of September, two days before the patient applied to me for relief. I opened the pulp-chamber from the lingual surface of the tooth, and found the pulp in a state of acute total pulpitis, which had extended somewhat into the pericementum. An application of carbolic acid, tannin, and morphia was made, which greatly relieved the patient. About one hour later I renewed the application, and after a few minutes introduced arsenious acid, and then dismissed the patient, who felt greatly relieved. The next day I extracted the pulp by means of a broach, and immediately immersed it in a very weak solution of chromic acid. A section of this is exhibited in Fig. 174. The patient, who at that time lived in the country, came back two days afterward to thank me for the cure of her neuralgia, which, up to this time, has not recurred.

III. On June 1, 1878, I inserted for Dr. H. an oxychloride filling in the right upper first molar, which had previously been filled with amalgam. The cavity was large, involving the distal and grinding-surfaces, with half of the lingual wall broken off. On August 21, 1880, I restored the lost portion of the tooth with gold, but left much of the oxychloride cement over the pulp-cavity. The walls of the cavity were quite sensitive under the bur, so much so that my patient, who in all other operations I had previously performed for him never said a word of the pain produced by excavating, in this instance remarked that the drilling in some places was very painful. There had been no pain whatever previous to the introduction of the gold, but about a week after the operation was completed the tooth became sensitive upon percussion and mastication, without signs of pulpitis. About two weeks later my patient was suffering from an acute alveolar abscess situated above the buccal roots of this molar tooth. I immediately tried to open the pulp-chamber, but could only go a little way into the dentine, when the patient informed me that the drilling caused him severe pain, analogous to the excavating of a sensitive tooth. I abstained from drilling any further, filled the small hole with gutta-percha, and began the treatment of the abscess through the gum at the buccal surface, but with no success. The abscess was continually discharging until the beginning of December, when I removed the gutta-percha, and, with a sharp drill, perforated the pulp-chamber, but, to my surprise, found the pulp alive and bleeding freely. I then, as quickly as possible, capped the pulp in the usual way, and filled the outer portion of the drill-hole, which had been widened with a larger bur up to the cap, with oxyphosphate cement, concluding to wait a few weeks longer, and then, if the abscess did not heal, to devitalize the pulp. On January 23, 1881, I removed the filling, together with the cap, in order to destroy the pulp, but found that the pulp had died recently, as there was no smell of putrefaction present in the pulp-chamber. I took out a large filling in the mesial surface of the tooth, and from this situation thoroughly exposed the pulp-chamber, from which I extracted a very large so-called "pulp-stone" of the size of a small pea, occupying the neighborhood of the buccal roots. This is the specimen which I have illustrated in Fig. 175, "so-called 'pulp-stones' composed of dentine with the features of primary dentine." The canals of the tooth were then examined, and I found the two buccal canals in a very putrid condition, but the lingual canal contained its recently-dead portion of the pulp without large calcified or eburnified masses. After the disinfection and filling of the pulp-canals the abscess began to heal, and the tooth to-day is as serviceable and comfortable as any other tooth in the mouth.

Diagnosis.—As stated before, to differentiate clearly between cases of true neuralgia and those depending upon eburnifications and ossifications of the pulp is sometimes impossible, although in most instances we are successful in localizing the origin of the trouble. The crowns of the teeth producing such reflex pains are sometimes perfectly sound, or they have previously been filled. In the latter case it is likely that a large metallic or oxyphosphate filling has been placed too near the pulp. In these cases the diagnosis is usually made by the application of hot and cold water, taking the precaution to separate the suspected tooth either with the rubber-dam, napkins, or bibulous paper. Thermal changes always produce great pain, and the sudden application to the seat of the trouble of agents which produce them often enables us to locate the offender. Quite different, however, are those cases in which the crowns of the affected teeth have never been filled, and are apparently healthy. While in the former instance the disease is usually limited to the tooth that had previously been filled, in the latter instance the trouble often originates more or less from two or more teeth on the same side, in which event all the teeth of the affected side will react upon the application of hot or cold water, although sometimes this reaction may be wanting. In such cases percussion has proved of great service to the writer. In the percussion test, however, we must carefully exclude all devitalized teeth, which are sometimes sensitive to percussion while the patient is affected with neuralgic pains, although their pericementum may be healthy. Teeth the pulps of which are affected by eburnifications or ossifications are a trifle loose in their sockets, and yield, upon percussion, a *slightly* dull sound.

The subjective phenomena connected with eburnifications or ossifications of the pulp-tissue are marked by great pains of the affected side, which are seldom localized in the pulp of the tooth producing the disturbance, but are usually more pronounced in neighboring parts of the nervous system. The affected nerves, in the beginning of the process, are slightly sensitive to sudden thermal changes, which sensitiveness lasts, as a rule, not over one minute. But with every attack the pain increases in severity, and although seldom lasting longer than from one to three minutes at a time, is most excruciating. One patient described these pains to be similar to that of a strong interrupted current of electricity going through the teeth and face. The paroxysms of pain may occur once or twice in twenty-four hours, or they may return every five minutes. When the patient has suffered for some time, we often observe a lameness of the muscles of the affected region, which in some instances even become sore to the touch. Such an attack may last a week or a month, and the duration and recurrence of the pain seem to be influenced by changes in the weather as well as by locality. Damp and cold weather is apt to bring on an attack of pain, while dry and warm weather is said to postpone it.

Differential Diagnosis.—From what has been stated above it is evident that most of the teeth, the pulps of which are affected by eburnifications or ossifications, contain no deep-seated carious cavities. Teeth, therefore, exhibiting large or deep-seated carious cavities, reaching the vicinity of the pulp, are to be excluded from this category of pulp-diseases. There is, however, one form of pulpitis, *total hyperplasia*, the subjective symptoms of which are somewhat similar to those of eburnifications and ossifications of the pulp. The similarity in the pain of these two diseases is explained by the fact that upon examination with the microscope we always find the pulps to be composed more or less of fibrous connective tissue, which easily gives origin to new formations of bone or dentine; the difference, however, being that a pulp suffering from total hyperplasia is more or less exposed, and the patient usually is able to localize the pain.

Hyperostosis of the Roots of the Teeth has sometimes been confounded with eburnification or ossification of the pulps, both indeed often presenting the same symptoms. In one instance observed by the author, a patient about thirty years of age, whose dental arches were much crowded, had suffered intermittently from severe neuralgia, sometimes on one, sometimes on both sides of the face. The teeth were not affected by thermal changes nor by alterations in the weather, and upon the extraction of the four wisdom-teeth the pain ceased and never returned. Unerupted lower wisdom-teeth, when the arch is too small to accommodate all the teeth, may give rise also to pain, which may be confounded with ossifications or eburnifications of the pulp. These, however, are easily recognized by the inflammation they usually produce in their surroundings. When the seat of the trouble is thought to be in a tooth, the only method to give relief and make the diagnosis certain is to open the tooth and devitalize the pulp.

Prognosis.—When the seat of the trouble is discovered, the pulps extirpated and the root-canals filled, the severe pains will never return. In many instances, however, patients during their paroxysms of pain have had the teeth extracted without discovering the one containing the eburnifications or ossifications, which was left in the mouth, the pains of course continuing. The writer once met a gentleman who, upon the advice of his physician, had all his posterior teeth removed, first those of the upper, then those of the lower jaw, but the pain persisted for about eighteen months longer, when it localized itself in an upper cuspid. This tooth was opened, the pulp devitalized and extirpated, and the canal was filled, since which time the pains have never returned. Upon examination, I found the pulp to be crowded with small eburnifications.

c. **Atrophies of the Pulp** are of rare occurrence, and little is known of them so far as clinical observations are concerned, as in most instances we are unable to make a correct diagnosis from the external appearances of the affected teeth. J. Arkövy mentions four forms of atrophy of the pulp,—viz, simple, sclerotic, reticular, and total atrophy. As, however, simple and total atrophies of the pulp, from a clinical as well as from a histological point of view, are of little importance, I shall confine myself to the description of the two most important diseases of this type,—viz, *sclerotic atrophy* and *reticular atrophy*.

SCLEROTIC ATROPHY OF THE PULP.—*Diagnosis.*—This disease is met with in apparently sound teeth, as well as in those whose crowns have been the seat of caries. The filling of the cavity of a tooth apparently has no influence over this disease of the pulp. From the external appearance of a tooth the pulp of which is affected with sclerotic atrophy, we are unable to make a correct diagnosis. When this disease occurs in teeth with deep-seated caries that does not quite reach the pulp-chamber, there is usually an uneasy sensation in the tooth, similar to that in irritation of the pulp. A differential sign is that when the cavity of a tooth, the pulp of which is affected with sclerotic atrophy, is disinfected and filled, the sensitiveness remains, while in one with an irritated pulp it will usually cease after one or two days.

The prognosis of pulps with sclerotic atrophy seems to be fair, as a pulp so affected may live for many years without causing severe disturbance. The author has observed one case, a right lower first molar, in the mouth of a healthy lady. In May, 1880, the tooth was somewhat sensitive at times, and upon examination I found a carious cavity in its mesial surface, which was prepared, disinfected, and filled with gutta-percha, without any subsequent change in the sensation of the tooth. In September, 1893, the lady had a fall which loosened the cuspid, the two bicuspids, and the molar teeth, and as they pained considerably, she insisted upon having them removed. Upon opening the molar, I found that a portion of the pulp was affected by sclerotic atrophy.

Reticular Atrophy of the Pulp.—*Diagnosis.*—This peculiar disease of the pulp occurs most commonly in teeth which have not been attacked by caries, although they may have been previously filled, the filling reaching the vicinity of the pulp-chamber. Teeth usually attacked by reticular atrophy stand alone in the dental arch, or articulate with their antagonists in such a manner that they are inclined either to the lingual or to the buccal side of the mouth. In such a case the pericementum is irritated every time the antagonizing tooth comes in contact with it. We also meet with this process in patients who have worn their incisors, by mechanical abrasion, nearly down to the pulp-chambers, and also in the teeth of aged persons. In color, very little or no difference is detectable between the teeth affected and those containing normal pulps. We also find some teeth in the later stages of pyorrhœa that contain pulps affected with reticular atrophy. The apices of their roots are usually slightly absorbed, but this is frequently observed in other teeth, the pulps of which are affected by reticular atrophy. Thermal changes exert no influence on such teeth. Most of them suffer more or less from chronic apical pericementitis. Percussion will yield a dull sound, although we meet with many cases in which no pericementitis is demonstrable from external appearances. When the pulp-canal of a tooth the pulp of which is affected with reticular atrophy is opened, the pulp appears like a quite thin flattened thread of catgut.

Subjective Phenomena.—Teeth whose pulps have been the seat of reticular atrophy do not cause any pain as such, except that sometimes, as is the case in pyorrhœa alveolaris, apical pericementitis may assume an acute form.

Differential Diagnosis.—This disease may be easily confounded with dry gangrene of the pulp, the only difference being that the apices of the roots of the teeth, the pulps of which have died of dry gangrene, are seldom affected by *chronic* pericementitis.

The prognosis of teeth the pulps of which have died from reticular atrophy is always good, as the filling of the root-canals is rarely followed by acute pericementitis.

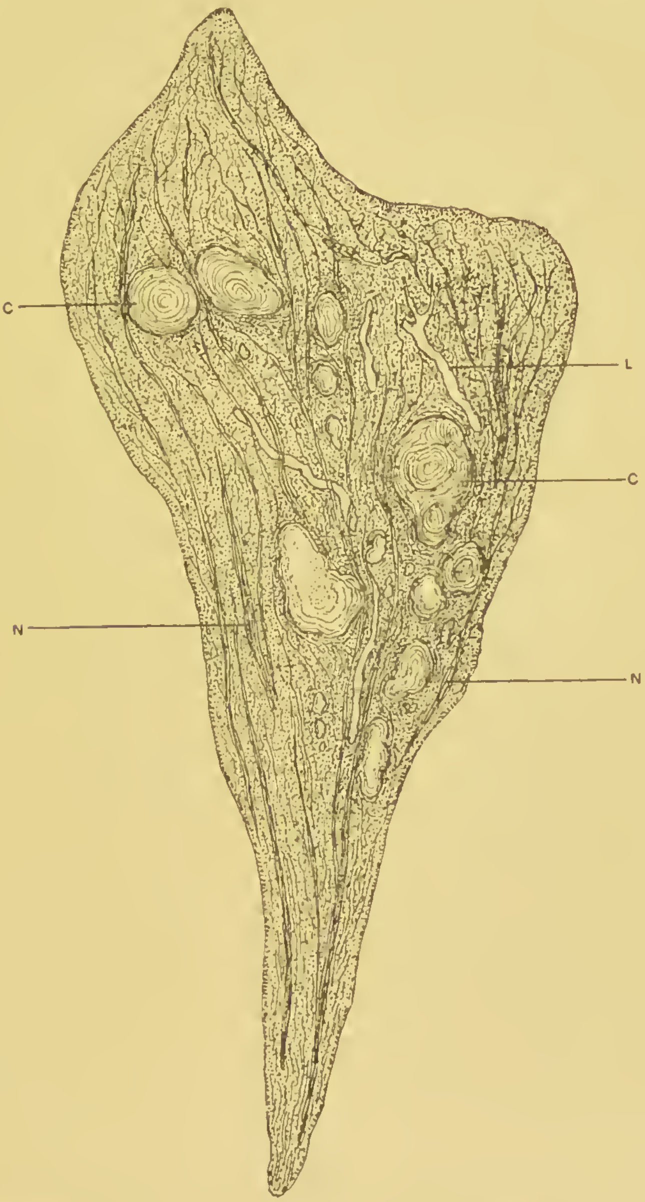
CHAPTER XXXVII.

MORBID ANATOMY OF ATROPHIES AND DEGENERATIONS OF THE PULP.

a. **Calcifications.**—According to C. Wedl, small nodular calcareous concretions of the pulp may be produced either by a calcification of cells, or by a direct impregnation of the organic substance with calcareous salts. The frequent occurrence of such nodules in the pulp is by no means confined to old age and the period of absorption of temporary teeth, but is not rarely met with in teeth of young men and women. Altogether calcareous depositions in the pulp, in the shape of both nodules and irregular needles or spiculæ, are frequently found (Witzel, Baume), but the cause of their formation is as yet unknown. A pronounced case is illustrated in Fig. 221. The slightly-lobulated calcareous globules are concentrically striated around one or several centers, which latter, judging from a slight stain with ammoniacal carmin, are not so intensely calcified as are their peripheral portions.

The age of the person apparently has nothing to do with the calcification of the pulp. Some very good observers have described it as the result principally of caries or loss of substance of the tooth by mechanical means. I have a great many specimens of pulps prepared from bicuspids and first and third

FIG. 221.

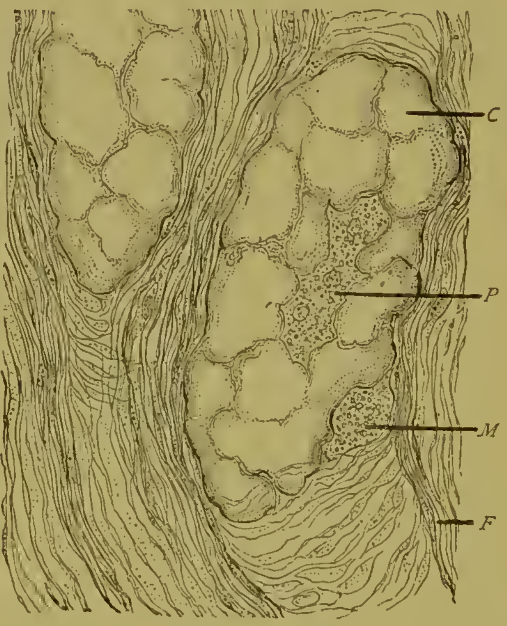


PULP WITH CONCENTRICALLY-STRIATED CALCAREOUS GLOBULES, SO-CALLED PULP-STONES. *C*, *C*, calcareous globules; *L*, lymph-vessel; *N*, *N*, bundles of medullated nerves. Magnified 10 diameters.

molars of young persons, which had to be extracted on account of irregularity or want of room, and most of them are externally perfectly sound. Some of the wisdom-teeth were removed when only one or two of their cusps had pierced the gum, but with only one exception all of these pulps exhibit greater or less quantities of calcific deposits as well as eburnifications. The same conditions I have observed in pulps derived from the teeth of old persons.

I extracted an unerupted wisdom-tooth from beneath the gums of a youth fifteen years of age, the pulp of which I found crowded with such calcareous globules. A rare instance of calcification of blood-vessels is drawn in Fig. 224. Here we notice a large portion of the blood-vessels of the pulp, mainly the arteries and capillaries, transformed into calcified solid rods of a markedly brown color. With medium powers of the microscope, we can easily ascertain that the majority of the vessels are solidified, only a few being choked with red blood-corpuscles. No doubt the primary cause of this calcification was an embolism of micrococci of an unknown nature in the arteries and capillaries, which did not cause pulpitis. Next, stagnation of the blood followed, and a number of red blood-corpuscles were transformed into caky, yellow-brown masses, which later became the seat of calci-

Fig. 222.



Calcification.—Pulp of a First Lower Molar of a Healthy Young Man Eighteen Years of Age. Extracted on account of Irregularity.

C, calcified masses composed of irregular lumps, probably former medullary corpuscles; *M*, medullary corpuscle unchanged; *P*, central plastid, free from infiltration; *F*, capsule of fibrous connective tissue. Magnified 300 diameters.

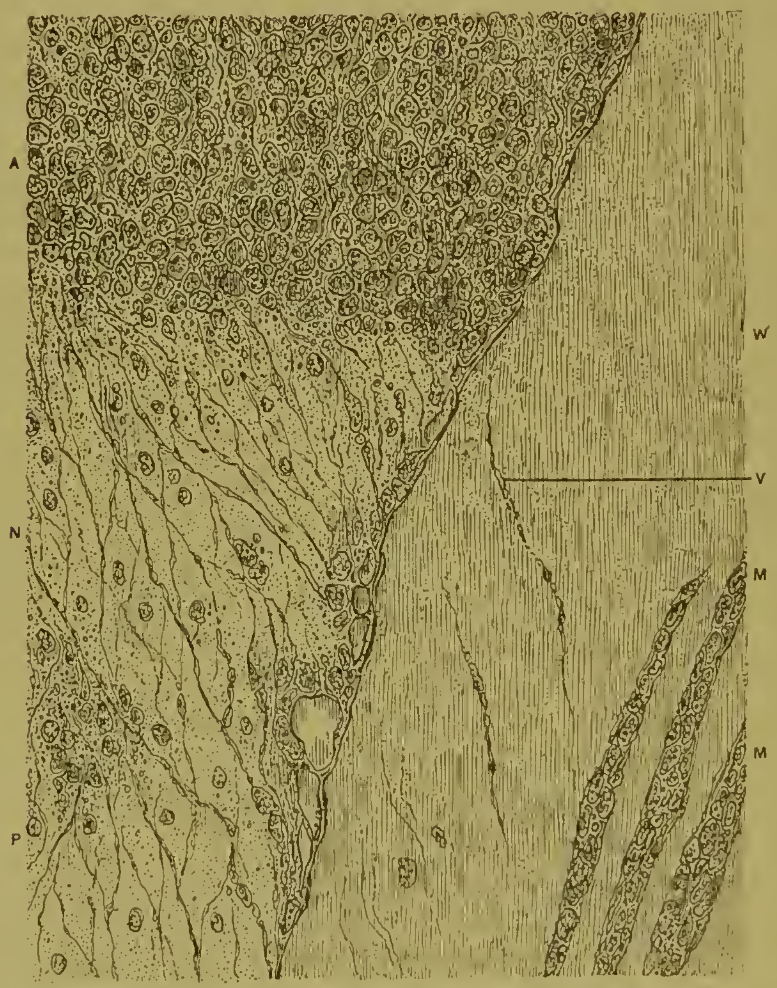
fication. Some of the vessels look homogeneous; others contain a number of caky masses, freely intermixed with micrococci. The veins have escaped calcification; only a few exhibit clusters of diffusely-pigmented cakes, evidently of the same origin as those in the arteries and capillaries.

Pulps containing a larger number of calcified spiculæ, as a rule, exhibit more fibrous connective tissue than myxomatous. Invariably around the calcified masses a dense layer of fibrous connective tissue has formed, ensheathing the calcified masses. Where these masses have fallen out an empty fibrous sac is left behind, in which there are neither endothelia, so characteristic of blood-vessels, nor oblong nuclei, which we see in the external perineurium of the bundles of medullated nerve-fibers. The presence of this envelope may convey the idea (especially if the calcified masses are elongated and appear like small lobulated sausages) that an obliteration has first occurred in the blood-vessel by a process which in other vascular systems, mainly that of the lungs, is known as "fatty embolism." The application of different reagents, especially osmic acid, has, however, convinced me that neither of these formations is a fat-embolism, and I am unable to observe any positive connection between the blood-vessels and the calcified masses. Sometimes it looks as if a capillary blood-vessel were attached to the space containing the calcified mass, or it may occur that a capillary vessel is suddenly dilated like a small aneurism, and in this widened portion we notice pieces of a calcified mass. The idea that the plasma of the blood laden with lime-salts accumulates in the capillaries of the pulp, and, unable to escape behind, deposits its lime-salts, I do not accept.

b. **Eburnification and Ossification.**—In one root of the right lower second molar of a physician about thirty-eight years old, circumscribed chronic pericementitis eventuated in chronic plastic pulpitis, with the new formation of fibrous connective tissue, and the formation of bone along the wall of the root-canal. (See Fig. 217.) In the other root of this tooth I found most of the bundles of the medullated nerves calcified, in appearance similar to Fig. 226. So intense was the pain caused by the calcification of the nerves, that the tooth had to be removed. Eburnification and ossification have been further dwelt upon in Chapter XXVI, on the so-called pulp-stones (secondary dentine), to which the reader is referred.

c. **Sclerosis.**—A peculiar metamorphosis is sometimes met with in the pulp-tissue, termed *sclerosis*, which is closely allied to waxy degeneration. Whether or not this process is the outcome of pulpitis I am unable to state. This much, however, is certain, that the unchanged tissue in the vicinity of a sclerotic portion is not infrequently seen inflamed. (See Fig. 223.) Sclerosis transforms the pulp-tissue into a horny-looking, nearly homogeneous or faintly granular mass, holding scanty atrophied nerves, but no blood-vessels. It differs from waxy degeneration in so much as sclerotic portions are not stained by ammoniacal carmin solution, which is invariably the case in waxy degeneration.

Fig. 223.

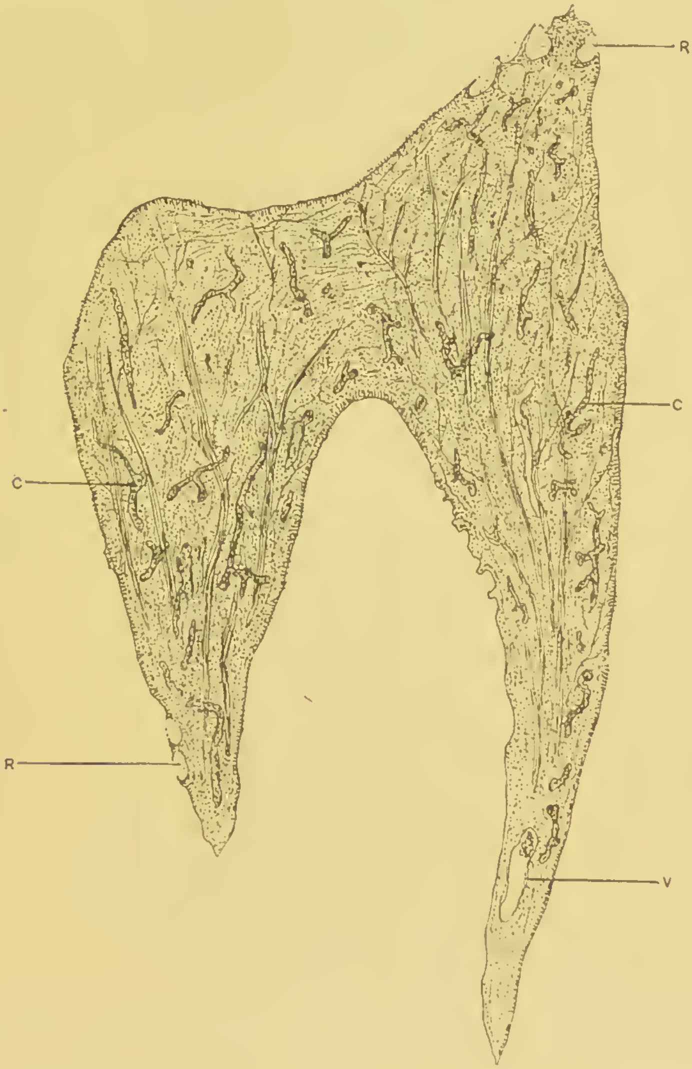


Waxy Degeneration of Pulp, with Acute Pulpitis.

W, waxy homogeneous mass; *M*, *M*, medullated nerve-fibers, broken up to inflammatory corpuscles; *V*, vestiges of medullated nerve; *P*, myxomatous pulp-tissue, slightly inflamed; *N*, medullated nerve-fibers; *A*, acute inflammation of pulp-tissue. Magnified 500 diameters.

d. **Reticular Atrophy.**—C. Wedl* first drew attention to this condition. Such atrophied pulps are recognizable with the naked eye by their flattened, shriveled appearance and finely-indented outer surfaces. Their color is lighter or darker, grayish-yellow or reddish-brown, according to the amount of necrotic blood present. The pulps have a dry appearance, are brittle, and of a consistence similar to parchment. Wedl attributes this atrophy to a withering of the reticulated connective-tissue cells, together with the peripheral blood-vessels and nerves.

Fig. 224.



Calcareous Embolism of Capillaries of the Pulp.

R, R, incipient reticular atrophy; *C, C,* arteries and capillaries choked with emboli; *V,* vein, holding a pigmented coagulum. Magnified 10 diameters.

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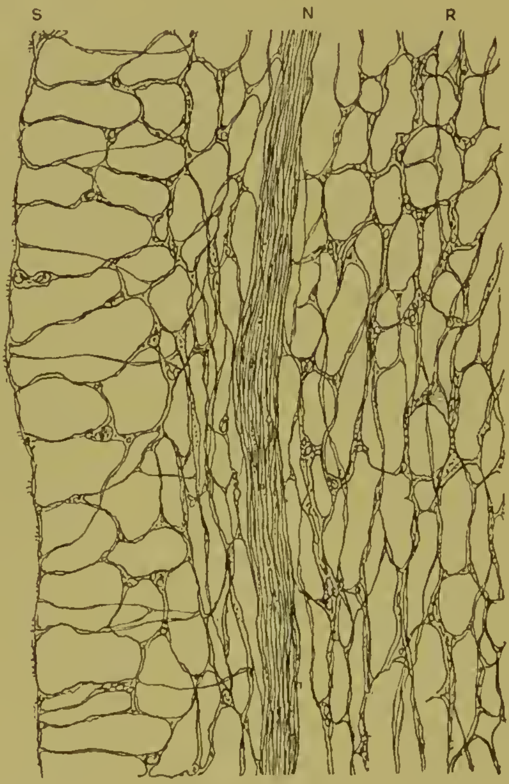
* "Pathology of the Teeth," 1872, page 237.

In Fig. 224 this process is illustrated in its incipient stage at the surface of both the coronal and root portions. This pulp contains a number of blood-vessels, mainly arteries and capillaries filled with calcareous masses of a yellow-brown color, which have obviously taken their origin from coagulated and disintegrated blood. The nerve-bundles are conspicuous by their small size.

In the highest degrees of this atrophy the pulp-tissue is transformed into a myxomatous reticulum, lacking lymph-corpuscles in its meshes, while the points of intersection show nuclei. (See Fig. 225.) The cause of this form of atrophy is a serous infiltration of the pulp-tissue, in consequence of which first a hydropic swelling, followed by a dissolution of the constituent elements, takes place. In the highest degree of such a serous infiltration, the entire pulp may be dissolved. In rare cases we find the pulp-chamber empty. This process is termed "dissolution of the pulp."

Fig. 225.

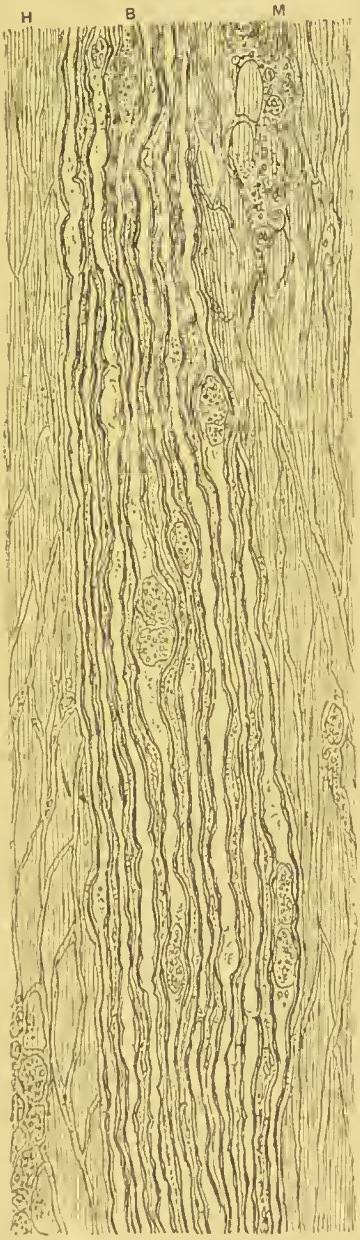


Reticular Atrophy of the Pulp (Wedl).

S, surface of pulp, overspread with fine offshoots; *R*, myxomatous reticulum, with nuclei at the points of intersection; *N*, fibrous bundles, a previous bundle of nerves. Magnified 500 diameters.

c. **Atrophy of the Nerves of the Pulp.**—Atrophy of the medullated nerves appears in three varieties,—*i.e.*, simple atrophy, transformation into fibrous connective tissue, and calcification. In sclerotic pulps we frequently meet with simple

Fig. 226.

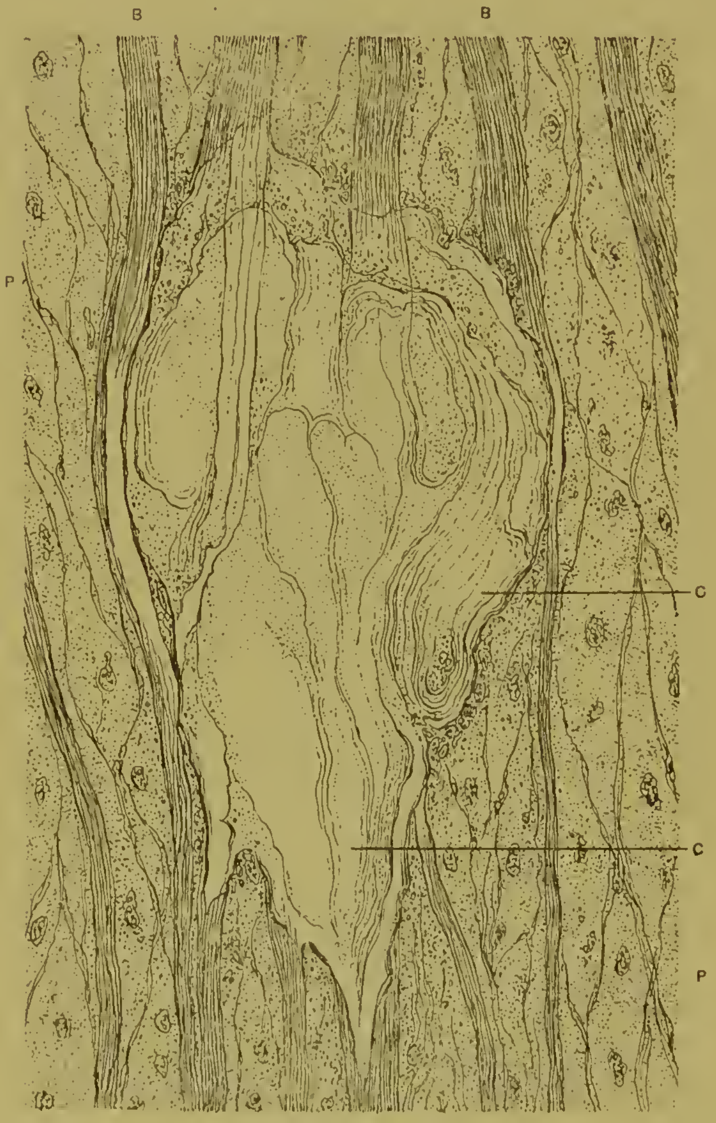


Atrophy of Medullated Nerves in a Living Pulp of an Upper Molar of a Person Twenty-five Years of Age.

B, bundle of nerves; *M*, vestiges of medullary corpuscles; *H*, nearly homogeneous sclerotic basis-substance. Magnified 1200 diameters.

atrophy of medullated nerves, both single and arranged in bundles. (See Fig. 226.) The nerves are much reduced in their bulk, being at the same time varicose in some places,

FIG. 227.

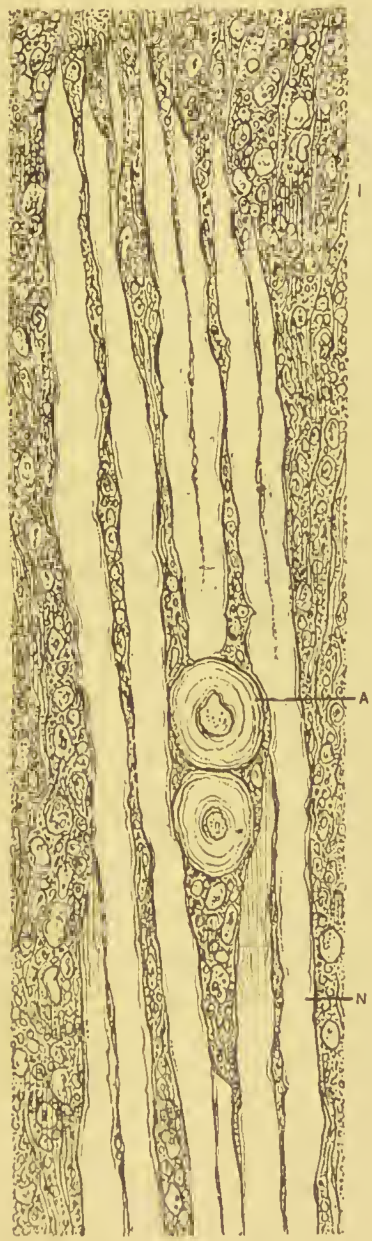


TRANSFORMATION OF BUNDLES OF MEDULLATED NERVES INTO PARTLY-CALCIFIED BUNDLES OF FIBROUS CONNECTIVE TISSUE. FORMATION OF CALCAREOUS GLOBULE. CROWN PORTION OF PULP.

B, *B*, partly-calcified bundles of fibrous connective tissue, previous medullated nerves; *G*, calcareous globule, embracing a number of fibrous bundles; *C*, thoroughly-calcified point of globule, directed toward the surface of the tooth; *P*, *P*, pulp-tissue crowded with cocci. Magnified 500 diameters.

where the myelin has not perished altogether. The double contour of Schwann's sheath is still recognizable even in the narrowest portions of the nerve-fibers, where myelin does not exist. I have been unable to find axis-cylinders in such atrophic nerves, not even in their transverse sections. The internal perineurium between the single nerve-fibers is invariably augmented.

Fig. 228.

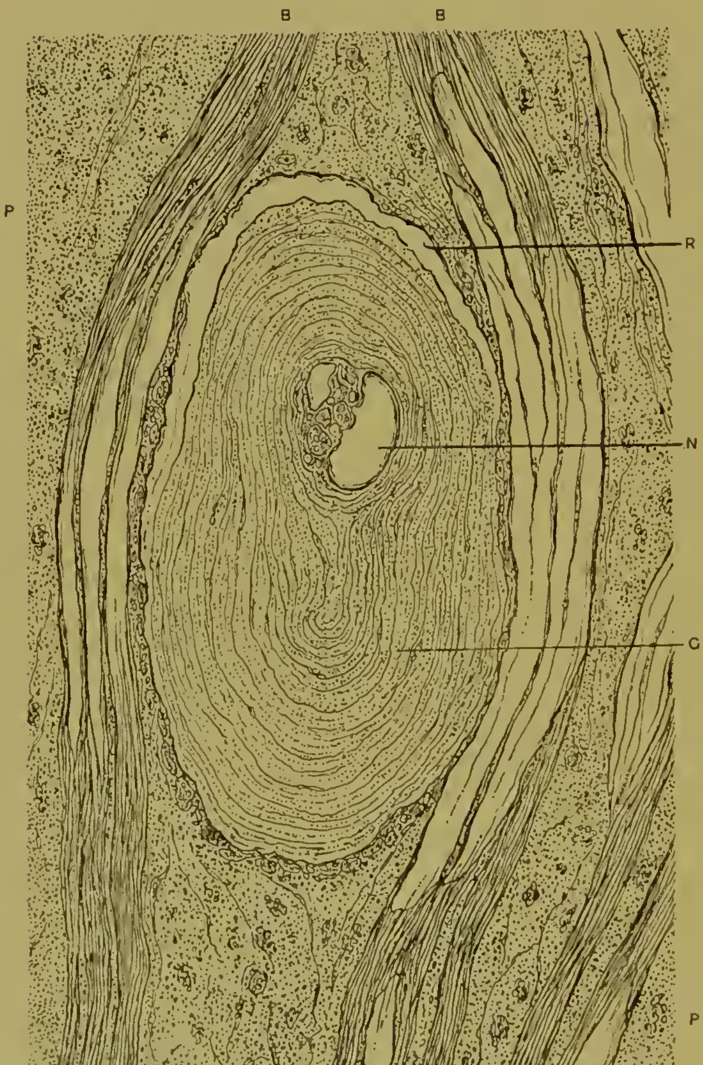


Calcified Bundle of Medullated Nerves. (From Fig. 217.)

N, calcified rod of a previous medullated nerve: *A*, calcified amylaceous corpuscle, from previous myelin: *I*, inflamed connective tissue, crowded with granules of lime-salts. Magnified 1200 diameters.

Fibrous degeneration of the nerves is of rare occurrence, as it seems, and is generally combined with the formation of calcareous globules. (See Fig. 227.) An example of this degeneration is also depicted in the figure of the reticular atrophy of the pulp. The bundles of medullated nerves become transformed into bundles of fibrous connective tissue, which latter can be traced even through the calcareous globule. The myxomatous tissue of the pulp is apparently unchanged.

Fig. 229.



Transformation of Bundles of Medullated Nerves into Partly-Calcified Bundles of Fibrous Connective Tissue. Incipient Formation of a Calcareous Globule. Root Portion of Pulp.

B, *B*, partly-calcified bundles of fibrous connective tissue, previous medullated nerves; *G*, globule made up of finely-striated basis-substance; *N*, calcified nucleus of globule; *R*, calcified rim of globule toward the apex of the root; *P*, *P*, pulp-tissue, crowded with cocci. Magnified 500 diameters.

Calcareous degeneration of the nerve-bundles seems to invade the medullated nerves after their transformation into fibrous connective tissue, though this preceding stage is not always traceable. Fig. 228 shows a calcified bundle of nerves, from a pulp affected with chronic purulent inflammation, abounding in calcareous deposits.

A combination of fibrous and calcareous degeneration is occasionally met with in pulps otherwise normal, or in a state of slight inflammation. Fig. 229 shows such a combination, and is valuable for demonstrating the devious course of nerve-bundles around a future calcareous globule, which for the present is made up of dense concentric layers of fibrous connective tissue, and is calcified only in a small portion of its center.

f. **Fatty Degeneration.**—According to Wedl, fatty degeneration is of frequent occurrence. A fatty pulp appears cloudy, and under the microscope crowded with fat-granules in all its constituent elements, including the nerves. Fatty degeneration is sometimes observed in the pulps of temporary teeth, while their roots are undergoing the process of absorption. Owing to the process of imbedding our pulps in celloidin, made liquid by ether, I have had no opportunity to observe this degeneration.

g. **Pigmentation.**—One of the rarest forms of degeneration of the pulp-tissue is *pigmentation.* In Fig. 219 there are depicted clusters of pigment, richest in one horn of the coronal portion of the pulp. These clusters appear rust-brown where seen in thin layers, and jet-black where they have accumulated in heavy masses. Unquestionably this pigmentation is the outcome of a previous hemorrhage, the more explicable since the pulp under consideration, besides showing calcareous deposits, is affected by chronic purulent pulpitis. In Fig. 224 diffuse pigmentation of the emboli in the blood-vessels is observed, likewise arising from the coloring-matter of the blood.

h. **Colloid Degeneration.**—C. Wedl (*l.c.*) has observed colloid corpuscles in the pulp. The author has had no opportunity to see such corpuscles in specimens of his own collection.

CHAPTER XXXVIII.

PERICEMENTITIS IN ITS CLINICAL ASPECTS.

In regard to the classification of the diseases of the root-membrane and the alveolar process, many systems have been published; but to find one which from both pathological and clinical point of view is absolutely satisfactory has proved well-nigh impossible.

Albrecht* was the first to give the subject some attention. He, however, classified the diseases with reference to their clinical aspect only. Magitot,† in 1882, published another and more extensive classification of pericementitis, adding many important points. In 1885, J. Arkövy‡ gave quite a detailed and good system of the diseases of the pericementum and the alveolar process. Several other classifications have been issued since; but neither of them being satisfactory to the writer, he attempted to formulate a new one. Although, as mentioned above, not free from objections with reference to its clinical aspect, the author hopes it may meet with approval.

Non-Purulent—1. Acute marginal pericementitis;
2. Acute circumscribed pericementitis;
3. Acute apical pericementitis;
4. Acute diffuse pericementitis;
5. Chronic hyperplastic partial pericementitis;
6. Chronic hyperplastic diffuse pericementitis;

Purulent.—7. Acute apical pericementitis;
8. Acute diffuse pericementitis;
9. Chronic marginal pericementitis;
10. Chronic circumscribed pericementitis;
11. Chronic apical pericementitis;
12. Chronic diffuse pericementitis.

Secondary Forms.—13. Chronic alveolar abscess;
14. Cementitis and eburnitis;
15. Periostitis, osteitis, and osteomyelitis;
16. Lymphadenitis, necrosis of the jaw-bones, empyema of the antrum.

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* "Die Krankheiten der Wurzelhaut der Zähne." Berlin, 1860.

† "Dictionnaire Encyclopedique des Sciences Médicales." Par Dechambre Paris, 1882.

‡ "Diagnostik der Zahnkrankheiten." Stuttgart, 1885.

I. Acute Non-Purulent Marginal Pericementitis.—This form of pericementitis occurs around the necks of the teeth, and is produced by chemical or mechanical irritants. The chemical irritation often is due to the decomposition of food left between the teeth, or forced under the gum in mastication. The majority of cases of this form of pericementitis, however, are caused by mechanical insults,—viz, fine pieces of bone, a part of a tooth-pick, the bristles of a tooth-brush, etc., which have entered the pericementum; badly-fitting clasps of artificial dentures, particles of oxyphosphate cement encroaching upon the pericementum; crowns and bridges; filling-materials protruding above the cavities; pieces of rubber-dam or floss-silk ligatures left under the margin of the gum more than twenty-four hours. Quite frequently this disease originates from salivary calculus, manifesting itself by a bluish ring upon the gums around the necks of the teeth. The inflammation in this form of pericementitis seldom extends beyond one-fourth part of the length of the root, and is mostly observed in the pericementum of the approximal surfaces of the roots of the teeth, except when due to an accumulation of salivary calculus, in which case it is mostly seen upon the lingual or labial surfaces, though sometimes encircling the entire neck of the tooth.

Diagnosis.—Acute non-purulent marginal pericementitis is characterized by the bright-red color of the gum covering the inflamed pericementum. The gum appears more or less detached from the neck of the tooth, and an instrument may easily be passed under it. An instrument coming in contact with the inflamed pericementum causes pain and more or less hemorrhage. Salivary calculus, as before mentioned, causes a bluish color of the gum around the neck of the tooth. It can readily be detected by an instrument which, passed over salivary calculi, will impart to the fingers the sensation of roughness characteristic of this substance; while, in absence of tartar, the neck of the tooth appears smooth. The tooth usually is somewhat sensitive upon percussion in the direction of the inflamed portion, at the same time eliciting a somewhat dull sound.

Subjective Phenomena.—Acute non-purulent marginal pericementitis seldom produces acute pain, but rather an uneasy, annoying sensation. The tooth is sensitive to mastication and pressure, and usually to thermal changes. When produced by salivary calculi, the patient scarcely experiences much sensation, except in an aggravation of the inflammatory process by particles of food lodged under the gums.

Differential Diagnosis.—Although in the majority of instances the patient is able to localize the disease in the root-membrane, there is a possibility of confounding acute non-purulent marginal pericementitis with irritation of the pulp. In some instances we find small, deeply-seated carious cavities under the margin of the gums, which likewise may produce an inflammation of the marginal portion of the gum. In most cases, however, a fine exploring instrument will readily enter the carious cavity. Should the latter be situated in the approximal surfaces of one of the second or third molars, especially in short teeth, where the necks are almost as large as the crowns, this procedure may become difficult.

Prognosis.—After the removal of the irritant and the disinfection of the mouth, the inflammation in the gums and pericementum soon abates, unless the general health of the patient be much impaired, in which case the inflammation tends to become chronic.

II. Acute Non-Purulent Circumscribed Pericementitis.—This form of pericementitis mostly involves one side of the root, or may encircle the entire root about its middle, without, however, affecting the apical portion of the pericementum. The area of inflammation seldom extends over the entire root, unless the process has become chronic.

Arkövy, who gives a good description of this disease, mentions two forms: "periodontitis acuta circumscripta consecutiva," and "periodontitis acuta circumscripta idiopathica." Since both forms are identical, except in their origin, I shall describe them under one head. Arkövy furthermore claims that acute non-purulent circumscribed pericementitis arises from acute total pulpitis. My specimens and clinical observations show, on the contrary, that the pulpitis is the result of the pericementitis, as in most instances I have observed a new formation of bone or secondary dentine in the pulp-chamber, corresponding to the inflamed pericementum on the outer surface of the root, especially in cases due to constitutional disturbances.

Acute non-purulent circumscribed pericementitis may originate either from mechanical violence or constitutional disturbances. Among the former I will enumerate hard biting, or a blow applied in a more or less oblique direction to the root.

Teeth standing isolated have more freedom of motion than those closely approximated by others; thus we observe acute non-purulent circumscribed pericementitis mostly in such teeth. J. Foster Flagg* was the first to draw attention to the fact that this disease sometimes is produced by constitutional derangements, an assertion which fully concurs with my own observations.

Diagnosis.—Teeth affected by acute non-purulent circumscribed pericementitis do not appear looser in their sockets than the other teeth in the mouth, nor longer when they articulate. Since the disease attacks both sound and decayed teeth, the etiology must be carefully considered in order to establish a diagnosis. It mostly lasts from one to three days, except when caused by constitutional disturbances, in which case chronicity is apt to ensue. The teeth, during the first two or three days of the affection, are but little sensitive to cold, while warmth will produce no alteration. The main characteristic which will aid us in the diagnosis of acute non-purulent circumscribed pericementitis is percussion and pressure upon the crown of the affected tooth, if possible in at least three directions,—viz, upon the grinding-surface, respectively the cutting-edge; upon the labial, respectively the buccal surface; and upon the lingual surface. When the pericementitis is localized mainly or exclusively upon the lingual portion of the root, which happens in the majority of instances, percussion upon the labial respectively the buccal surface of the tooth will yield a slightly dull sound and be somewhat sensitive. Percussion or pressure upon the affected tooth in the other two directions mentioned will elicit neither pain nor dullness.

Subjective Phenomena.—Acute non-purulent circumscribed pericementitis, when produced by mechanical violence, causes but little annoyance to the patient, except when pressure or percussion is applied in the manner described above. When, however, the disease has originated from constitutional derangements, the subjective symptoms are more pronounced, at the same time affecting two, or even more, teeth. In almost all cases I have seen, I have noticed, besides the acute non-purulent circumscribed pericementitis, more or less erosion, and an acid reaction of the saliva. The teeth are quite sensitive to cold, but I could not ascertain whether this was due to the pericementitis or to the erosion. Sometimes, especially in teeth standing isolated, the inflammatory process extends to the neck of the tooth, and often becomes chronic and purulent, presenting the features of a so-called "blind abscess" (chronic purulent circumscribed pericementitis).

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* *Dental Cosmos*, 1878.

Differential Diagnosis.—The only disease with which acute non-purulent circumscribed pericementitis could be confounded is chronic purulent circumscribed pericementitis. The latter is characterized by the soreness upon pressure with the finger on the gum over the root of the affected tooth, whereby a small quantity of pus may be seen to exude at the neck of the tooth. The latter symptom is never observed in *acute non-purulent* circumscribed pericementitis.

The prognosis of teeth affected with acute non-purulent circumscribed pericementitis as the result of mechanical violence is always good; while, on the contrary, cases depending upon constitutional trouble sometimes become chronic. In the latter instance the pericementitis induces chronic hyperplastic pulpitis, followed by calcification of the blood-vessels and nerves of the pulp, usually terminating in the loss of the tooth.

III. Acute Non-Purulent Apical Pericementitis.—This type of pericementitis is of frequent occurrence, and is mostly produced by pulpitis and by mechanical and chemical irritants. Among the forms of inflammation of the pulp that may induce acute non-purulent apical pericementitis are the following: acute total pulpitis, acute purulent pulpitis, chronic total hyperplasia of the pulp, and moist gangrene. The last-named disease, if rapidly progressing, is the most frequent cause of acute non-purulent apical pericementitis, which, in this instance, is prone to involve the entire pericementum of the tooth. Apical pericementitis may be induced by chemical irritants, such as filling-materials, which during the process of filling the pulp-canal have been forced through the apical foramen of the root of the tooth. The same untoward result may occur when chemical irritants, such as corrosive sublimate, chloride of zinc, pure carbolic acid, iodine, etc., employed in the disinfection of the root-canal, have come in contact with the pericementum through the apical foramen. We also observe this form of pericementitis after extensive operations in restoring large portions of teeth with gold. The protracted or too severe malleting upon a tooth, as well as a protruding filling, a crown, a bridge, or an artificial tooth that causes more pressure upon its antagonist than normal, often produce an acute non-purulent apical pericementitis. This may likewise result from too rapid regulating, wedging, or anything that will force the teeth out of their normal position, especially when the force is applied in the direction of the apex of the tooth.

Diagnosis.—Acute non-purulent apical pericementitis is easily recognized by slight percussion, either with an instrument or with the finger-nail. In teeth possessing but one root, the dullness as well as the soreness elicited upon percussion in the direction of the apex of the root are quite marked; while in teeth having two or three roots, both dullness and soreness upon percussion are not so pronounced, unless the vibrations are produced in the direction of the apex of the affected root. The same will be the result upon pressure which, in the direction of the apex of the affected root, produces slight pain, while when applied laterally to the affected tooth it is painless. Acute non-purulent apical pericementitis does not raise the teeth out of their sockets, consequently they are not looser than the other teeth in the mouth. As this disease frequently occurs in teeth which either have been filled or contain carious cavities, a careful examination must be made in regard to pulpitis, or the particulars in regard to the filling of the carious cavity or the pulp-canal of the tooth.

Subjective Phenomena.—Acute non-purulent apical pericementitis usually becomes noticeable from ten to twenty-four hours after the irritation. The pain, in most cases starting instantaneously during mastication, is localized by the patient in the affected tooth. The tooth does not appear elongated, but is sensitive in mastication. The pain may last from one to three days after the removal of the irritant.

Differential Diagnosis.—By carefully considering the etiology, the diagnosis, and the subjective symptoms of acute non-purulent apical pericementitis, it is barely possible to confound this disease with any other form of pericementitis. It may, however, sometimes be mistaken for chronic partial hyperplastic or acute purulent apical pericementitis.

Chronic partial hyperplastic pericementitis is characterized by being quite sensitive to pressure upon the gum in the region of the apex of the root of the affected tooth, which pressure will yield negative results in the case of acute non-purulent apical pericementitis. Acute purulent apical pericementitis may be differentiated by the rapidity with which it develops, the severe pulsating pains, as well as the elongation of the tooth, all of which phenomena are absent in acute *non*-purulent apical pericementitis.

Prognosis.—According to the origin of acute non-purulent apical pericementitis, the prognosis of this disease is either quite favorable or not. If the disease has arisen from external violence, such as too heavy or too long-continued malleting, too rapid regulating, fillings, crowns, or artificial teeth left too high, or wedging, the inflammation upon the removal of the irritant will usually subside in from one to three days. If, on the contrary, acute non-purulent apical pericementitis is produced by acute purulent pulpitis, by gangrene of the pulp, or by filling-materials or other foreign substances pushed through the apical foramen of the root, the prognosis becomes unfavorable. In some instances the disease assumes a chronic hyperplastic character; in others it may develop into an acute purulent apical pericementitis, the prognosis of which is stated in the respective paragraphs of this chapter.

IV. Acute Non-Purulent Diffuse Pericementitis.—This disease usually extends over the greater portion of the root-membrane, although we seldom find the cervical portion of the pericementum involved. Arkövy states that this form of pericementitis is accompanied by a considerable degree of œdema of the involved portion of the pericementum. Acute non-purulent diffuse pericementitis mostly occurs in consequence of pulpitis, traumatism, mechanical or chemical irritation at the apical foramen, and sometimes constitutional derangements. Of the diseases of the pulp, only those of a quite acute character will produce this form of pericementitis,—viz, acute total pulpitis, or moist gangrene. In a traumatic way the disease may be produced by a heavy blow, a fall, the too rapid wedging or regulating of the teeth. Sometimes it occurs that in the treating or filling of pulp-canals severe chemical irritants are pushed through the apical foramen of the root or enlarged dentinal canaliculi; furthermore, pieces of filling-materials, either metallic or non-metallic, or a broken nerve-instrument protruding through the apical foramen, may lead to an acute non-purulent diffuse pericementitis.

Diagnosis.—As we always notice considerable swelling of the pericementum, the affected tooth will be found quite loose in its socket, and the crown raised considerably above the level of the other teeth. Slight percussion upon the affected tooth yields a very dull sound; at the same time the tooth is quite sensitive to pressure, especially in the direction toward the apex. The corresponding gum usually exhibits some redness, and is sensitive to pressure, without indication of fluctuation. When this disease occurs in teeth with living pulps, an irrigation of cold water produces pain, which symptom always calls for a careful examination of the pulp-chamber.

Subjective Phenomena.—The pain of acute non-purulent diffuse pericementitis develops gradually about twenty to thirty hours after the irritation, at least in cases originating from mechanical or chemical violence. The pain in the latter instances is acute and drawing. When, however, the disease originates from acute total pulpitis or gangrene of the pulp, the patient complains of severe throbbing pain, not only in the affected part, but over the whole side of the face. As the tooth is raised out of its socket considerably above the level of the other teeth, mastication, or even the closure of the mouth, is rendered impossible. This state may continue for three or four days, and sometimes may last a week, when the inflammation either gradually abates or becomes chronic. The pain usually is much more severe toward evening, especially when the patient occupies a recumbent position, or after taking alcoholic stimulants or active bodily exercise.

Differential Diagnosis.—Acute non-purulent diffuse pericementitis may be confounded with acute or chronic purulent diffuse pericementitis. Acute purulent diffuse pericementitis is principally characterized, in contradistinction to acute non-purulent diffuse pericementitis, by the former never being sensitive to cold applications: the presence of fever; besides, upon slight pressure on the gums pus will be eliminated. The gums in the purulent form are seldom attached tightly to the neck of the tooth; they are considerably swollen, and at the same time fluctuating.

Chronic purulent diffuse pericementitis principally differs from the acute non-purulent diffuse form in the character of the subjective phenomena, which in a chronic disease are never intense.

The prognosis of acute non-purulent diffuse pericementitis, in the majority of instances, is favorable for the preservation of the tooth, although in cases where chemical irritants or foreign bodies pushed through the apical foramen have produced the inflammation, the prognosis is not so favorable. In the latter instances, as well as in those originated from gangrene of the pulp, an invasion of strepto- and staphylococci takes place, followed by purulent pericementitis.

V. Chronic Hyperplastic Partial Pericementitis.—Under this head I propose to classify the growths of the pericementum occurring around the cervical portion and sometimes lodging in carious cavities about the necks of the teeth. In this situation they may easily be confounded with a hyperplastic pulp, especially when in a largely-decayed molar the pericementum has grown through a perforation at the bifurcation of the roots. This disease, however, is not exclusively found in carious teeth, but also in those with apparently sound crowns. The etiology is not perfectly clear in all cases. The author, however, has frequently found it to be the result of chronic purulent marginal pericementitis (pyorrhœa alveolaris).

Diagnosis.—In most instances chronic hyperplastic partial pericementitis is readily recognized by the presence of granulation-tissue. The latter appears knob-shaped at one side of the neck portion of the pericementum in varying sizes. When these growths occupy carious cavities, they seldom surpass the size of the head of a pin or that of a pea. Exceptionally we meet with granulations the size of a walnut or even larger, mostly occupying the labial, respectively buccal surface of otherwise sound teeth. The tumor in the latter cases is attached by means of a pedicle and lobulated upon its upper surface, while the lower one resting upon the gum usually is smooth. The so-called granulomata are richly supplied with capillary blood-vessels, and therefore bleed profusely when wounded. The teeth are not looser in their sockets than the other teeth in the mouth, and percussion elicits a dull sound only in the direction of the diseased portion of the pericementum.

Subjective Phenomena.—Chronic hyperplastic partial pericementitis does not produce pain as such, except when the growth becomes irritated in mastication or by exposure to pronounced thermal changes.

Differential Diagnosis.—When chronic hyperplastic partial pericementitis occurs in teeth the crowns of which are largely decayed at their cervical portion as above mentioned, it may easily be confounded with granuloma of the gum or partial hyperplasia of the pulp. In such instances the granuloma of the pericementum grows into the carious cavity, and sometimes, in devitalized teeth, may even occupy the pulp-chamber. A thorough examination is not always possible at once, since the granulations of the gum and the pulp, as well as those of the pericementum, bleed profusely. It is advisable to insert a piece of cotton, saturated with pure carbolic acid, into the cavity of the tooth, which after twenty-four hours will enable us to make a clear diagnosis. When chronic hyperplastic partial pericementitis occurs in teeth in the early stage of pyorrhœa alveolaris, the disease under consideration is easily recognizable. Here it sometimes happens that the granulations have destroyed small portions in the neck or the root, which latter appear in the form of cup-shaped excavations.

Prognosis.—So long as chronic hyperplastic partial pericementitis occurs in places accessible to removal of the granuloma, and prevention of its recurrence by the application of strong escharotics, the tooth need not be sacrificed. When, on the contrary, the granulations have absorbed portions of the root, the prognosis becomes doubtful. The sharp edges of the excavations on the root irritate the pericementum even after the granulations have been destroyed, and usually give rise to an incessant new formation thereof.

VI. Chronic Hyperplastic Diffuse Pericementitis.—This form of pericementitis embraces the new formations occurring in the pericementum below the margin of the alveolus. They mostly are built up of granulation-tissue, gradually absorbing the roots of the teeth as well as the alveolus of the jaw-bone. This form of pericementitis predominates in teeth of young patients, especially when the roots were not fully formed at the time of death of the pulp. We also notice it in teeth the pulp-canals of which have been filled with gold wire. No pus is noticed in hyperplastic pericementitis unless it is accompanied by a purulent form of pericementitis.

The diagnosis of chronic hyperplastic diffuse pericementitis cannot always be established with certainty. Although such teeth are loose, and appear considerably elongated, the gums around their necks may be normally attached, and a probe cannot be easily introduced along the root of the tooth. When, however, the gum encircling the neck has lost its attachment to the tooth, the granulomata in some instances can be distinctly felt by means of a probe. The latter feature mostly prevails in diffuse cases; when the granuloma involves only the apical portion of the pericementum, an examination by the probe is impossible. The gum in the vicinity of the affected root usually appears almost normal.

Subjective Phenomena.—Chronic hyperplastic pericementitis seldom causes pain or much discomfort to the patient. Teeth thus affected are quite loose and somewhat elongated, although the surrounding gum shows little or no signs of inflammation. Pressure upon the tooth in the direction of the apex of the root usually is painful.

Differential Diagnosis.—Chronic non-purulent diffuse pericementitis may easily be confounded with chronic purulent apical, as well as with chronic purulent diffuse pericementitis. In fact, in both of these forms where the inflammatory process has lasted for some time, we often observe new formations of fibrous connective tissue and bone-tissue in the vicinity of the inflamed pericementum. The characteristic features of the disease in question are not well marked.

The prognosis of teeth affected with chronic non-purulent diffuse pericementitis is always bad, since the root gradually becomes absorbed, and the tooth, unless extracted, in course of time falls out.

VII. Acute Purulent Apical Pericementitis.—As every purulent inflammation depends upon an infection of the tissue with staphylococci, sometimes combined with streptococci, acute purulent partial pericementitis never occurs unless an infection with the above-named micro-organisms has taken place. The disease under consideration frequently is induced by gangrene of the pulp; also by acute or chronic purulent total pulpitis; eventually by septic nerve-instruments introduced into the pulp-canal or through the apical foramen. With regard to the aseptic condition of instruments, I would advise the utmost care; although I must admit that an *absolute* aseptic treatment in the mouth is next to an impossibility, even though the rubber-dam be applied. Bacteria are organisms so minute that they can only be detected by the microscope with a magnifying power of at least 600 diameters. The human mouth is crowded with micro-organisms, and they will adhere to everything coming in contact with it. Our fingers will transfer them to the handles of instruments, the hand-piece of the dental engine, napkins, towels, cotton, etc. Bacteria may even enter a pulp-canal although the instrument used was sterilized, and the hands after the application of the rubber-dam have been thoroughly washed. I am convinced that everything in the office coming in contact with the fingers of the operator is more or less infected with micro-organisms. If, therefore, a nerve-instrument touches a napkin, a towel, the rubber-dam, or anything which has been in contact with our hands, before they were thoroughly washed again, an infection of the pericementum may be the result. It is evident that an aseptic treatment of a pulp-canal without the application of the rubber-dam to the affected tooth is impossible. This fact no doubt explains the origin of many occult cases of acute purulent apical pericementitis.

Diagnosis.—Acute purulent apical pericementitis never occurs unless the pulp of the tooth be affected by total purulent inflammation, by gangrene, or in a devitalized tooth. The gum around the root of the tooth usually is but little swollen or altered in color, and unyielding, though somewhat painful to pressure. The tooth appears but little higher, and is only partially sensitive in mastication. Slight percussion upon the tooth, especially in a labio-lingual direction, is quite painful, and elicits a distinctly dull sound. Such teeth are seldom looser than the other teeth in the mouth.

Subjective Phenomena.—When a tooth becomes affected with acute purulent apical pericementitis, the patient notices soreness of the tooth about eight to twelve hours after the infection of the pericementum. This is followed by gradually increasing pain, which after about twenty-four hours becomes severe and of a pulsating character. The tooth now is extremely sensitive to cold, and even the inhalation of cold air produces pain. The affected side of the mouth feels quite hot, especially the gum in the neighborhood of the root of the diseased tooth. Toward evening the patient usually is attacked by fever, the severity of which, however, depends upon his constitution. The pains are much aggravated in the recumbent position, by active bodily exercise, or alcoholic stimulants.

Differential Diagnosis.—Acute purulent apical pericementitis may be confounded with acute non-purulent partial pericementitis, although the pulsating character of the pain always present in the former disease is never noticed in pericementitis, not terminating in suppuration.

The prognosis of teeth attacked by an acute purulent apical pericementitis, as a rule, is favorable, although much depending upon the constitution and the age of the patient, the shape of the pulp-canal, and the position of the tooth. Whenever the practitioner is able to obtain entrance through the apical foramen, by means of a fine broach, into the abscess, and thereby evacuate the pus, the pain will almost instantly cease. The tooth and pulp-canal, after proper treatment, may then be filled, which when successfully accomplished will preserve the tooth.

VIII. Acute Purulent Diffuse Pericementitis.—This disease is almost invariably the outcome of the one before described, its etiology being similar.

Diagnosis.—A tooth affected with acute purulent diffuse pericementitis is extremely sensitive to the touch with the finger, or even the tongue. It is quite loose in its socket, and appears considerably elongated above the level of the other teeth, so much so that the patient is unable to eat or even to close his mouth. The corresponding cheek or lip becomes œdematous, producing a marked disfigurement, and sometimes complete closure of the eyelids. The gum in the vicinity of the affected tooth always is swollen, and painful to pressure with the point of a finger. In some instances, upon pressure more or less pus will be eliminated around the cervical portion of the tooth. According to the severity of the process the inflammation is imparted to the alveoli and the pericementum of the neighboring teeth, to such an extent that only the characteristic color of the dead tooth will indicate the original seat of the abscess. Thermal changes, especially cold applications, are quite painful. Slight percussion, which ought to be applied gently, is extremely painful, and produces a dull sound. Should the neighboring alveoli be involved in the inflammatory focus, the tooth which is the original seat of the pericementitis will always elicit the comparatively dullest sound.

Subjective Phenomena.—The pain before the appearance of the œdema caused by acute purulent diffuse pericementitis, is stated to be among the severest of human sufferings. Its character is pulsating, affecting the whole side of the face, and is materially increased by the recumbent position, by bodily exercise, and alcoholic beverages. Although there are no intermissions of pain, it usually is worse toward evening, or at night. The pain steadily increases from hour to hour, until it becomes almost unbearable. A severe chill indicates that pus has formed. With still increasing pain fever sets in; the patient's temperature is elevated, the pulse accelerated, the appetite lost, and the tongue becomes thickly coated. The suffering continues from one to five days, when at once an œdema of the face makes its appearance, whereby the patient is relieved, the pain now assuming a more or less dull and intermittent character.

Differential Diagnosis.—Acute purulent diffuse pericementitis may be confounded with acute diffuse non-purulent, or chronic purulent diffuse pericementitis. The principal characteristic feature of acute purulent diffuse pericementitis is its initiation by a chill followed by fever, which never occurs in the non-purulent form.

Chronic purulent diffuse pericementitis may easily be discriminated from an acute one by the character of the pain and the absence of fever. In an acute inflammation the pains are severe, pulsating, and steadily increasing, while in chronic inflammation the pain is not severe, of a more intermittent and drawing character.

The prognosis of teeth affected with acute purulent diffuse pericementitis is almost as good as that of teeth attacked by the apical form.

The same rule is applicable in both instances,—viz, whenever we are able to evacuate the pus from the alveolus, either by incision through the gums or by means of a fine broach through the pulp-canal, or both ways combined, the tooth may be saved. To accomplish this, however, the pulp-canal as well as the tooth, after the disappearance of the abscess, must be thoroughly disinfected and filled. The greatest obstacles to treating such a tooth are both its looseness and the pain produced by the opening of the pulp-canal. This, nevertheless, in most instances can be accomplished by fastening the tooth to a ligature and pulling it by the string against the drill. In severe cases, the tooth, besides being ligated, must be held with two fingers by an assistant, while the canal is opened by a drill.

IX. Chronic Purulent Marginal Pericementitis, so-called "Pyorrhœa Alveolaris."—This disease has also been termed "pyorrhœa alveolo," Toirac by Desirabode: "cemento-periostitis," by Magitot; "gingivitis expulsiva," by Marchal de Calve; "alveolitis infectiosa," by A. Witzel: "Blennorrhœ der Alveolen," by Steinberger; and Riggs's Disease. The last name was coined in honor of Dr. Riggs, who was the first to give this disease special attention.

In regard to the etiology of the disease under consideration, few positive facts are known; but hypothetical speculations about it are quite abundant. Prior to the time of Riggs (1867), pyorrhœa alveolaris was believed to be a disease of the gums. Riggs himself was of the opinion that the disease was a necrotic condition of the alveolar border. In 1873 Magitot proved that the trouble was situated in the pericementum. C. Tomes first made the statement that pyorrhœa alveolaris was not due to deposits of salivary calculi, which, up to his time, was believed to be the cause. Tomes furthermore called attention to the fact that tartar is of secondary importance, and in many cases no calculi are present. Since that time much has been said and written on the subject, without, however, advancing anything of importance, except that many practitioners agreed in that the disease was not primarily due to a deposition of salivary calculi, but rather to systemic derangements. J. Arkövy calls this disease "caries alveolaris," and maintains that its origin is a necrotic process in the margin of the alveolus, which in later stages is transferred to the pericementum and cementum of the tooth. C. N. Peirce, in a paper read before the New York Odontological Society, November, 1893,* expressed the view that pyorrhœa alveolaris is principally due to a gouty diathesis of the system, and defines two forms of this disease. He says, "In one form of pericementitis the origin of the calcic salt is the saliva, and in the other form the blood. The former I shall designate a *ptyalogenic calcic* pericementitis, expressive of the idea that in its origin it is local, peripheral, and salivary. The latter I shall designate as *hæmatogenic calcic* pericementitis, expressive of the idea that in its origin it is constitutional, central, and associated with some modifications of the normal composites of the blood-plasma.

"*Calcic pericementitis may have its origin at the gingival borders, the tartar acting as a local and mechanical irritant, with the train of concomitant evils, such as irritation, inflammation, formation of pus, and absorption of gum and alveolar process.*

"*We have three distinct, abnormal conditions affecting the gums, pericemental or alveolo-cemental membrane, and alveolar process.*

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* *The International Dental Journal*, 1894.

The first is gum inflammation and destruction, caused by a mechanical irritant. Second, inflammation of the gingival borders without the presence of tartar. The third is a pericemental irritation commencing at or near the apical extremity of the root, due to the presence of some morbid composite of the blood, exuded with the plasma and infiltrating the alveolo-cemental membrane, and frequently deposited or precipitated upon the root of the tooth near its apex. This latter I designated true pyorrhœa alveolaris, or hæmatogenic pericementitis, and so intimately is it associated with some other local manifestation of a gouty diathesis, that I have believed and do now believe it to be but another local expression of that systemic condition."

While the views of Peirce have many followers, among whom are Edwin T. Darby, S. G. Perry, R. R. Andrews, A. P. Brubaker, and others, the contradictory opinions seem to be just as strong, as expressed by S. H. Guilford, M. L. Rhein, James Truman, R. Ottolengui, G. S. Allan, as well as the writer, and others. It cannot be denied that a superabundance of uric acid in the system may assist in producing pyorrhœa alveolaris; but it will not exert more influence in this direction than consumption, anæmia, nephritis, hepatitis, diabetes, arthritis, syphilis, typhoid, chronic diseases of the nervous system, etc., which are often found associated with pyorrhœa alveolaris. Furthermore, it is an established fact that sometimes uric acid is present in the system without producing either gout or rheumatism. We must therefore admit that the cause of the disease under consideration principally is a more or less chronic general ailment, and not due to any particular form. At the same time, we meet with many cases of pyorrhœa alveolaris which can be attributed to nothing but heredity. The disease is mostly limited to middle age, although exceptionally we see it in persons under twenty years.

Diagnosis.—Chronic purulent marginal pericementitis begins as an acute or a subacute inflammation in the cervical portion, soon becoming purulent and afterward chronic. In the early stages the gum is yet of a normal color, and detached from the neck of the tooth only in a small area,—as a rule, upon the labial surface. Salivary calculi seldom are seen in those places where the gum is found detached from the neck of the tooth, although it may be present upon the lingual or the approximal surfaces of the teeth. Exceptionally we meet with patients suffering from pyorrhœa alveolaris, in consequence of rheumatism, who have an abundant accumulation of calculi above the gum-margin. Sometimes we meet with pyorrhœa alveolaris in which the calculary deposit encircles the entire necks of the teeth; but in these instances the tartar had formed previously to the development of the disease under consideration. The deposits below the gum-margin which later accumulate upon the roots of the affected teeth usually have been called "seruminal tartar," in contradistinction to that found upon the teeth above the gum-margin. The former deposits are of a dark-brown or black color, and, as the disease progresses, gradually extend toward the apex of the root. In some instances the middle portion of the pericementum of the root remains intact, and at the first glance it appears as though the deposit at the apex of the tooth were in no connection with that found upon the neck. Closer examination with a magnifying lens, however, shows that the deposits in one or more narrow routes have obtained access to the apical portion. In the incipient stage of the disease the affected teeth are not looser than the others in the mouth, and the only symptom indicative of pyorrhœa alveolaris is the presence of pus upon pressure around the neck of the tooth. At first the quantity of pus eliminated is small, seldom more than about one drop in ten or twelve hours. The pus can be best exhibited by pressure upon the gum, gradually extending toward the cutting-edge, respectively the grinding-surface of the tooth. In advanced stages, however, the pus may flow continually from the sockets, causing a peculiar odor of the breath of the patient. With the progress of the disease the pericementum is destroyed by degrees, and the so-called pocket between the gum and the neck of the tooth becomes deeper. In some instances we notice the margin of the gum to be thin and sharp; in others the gum appears thick and almost hypertrophied, which fact seems to have little to do with the stage of the disease, as both conditions are noticed in deep as well as in shallow pockets. As the destruction of the pericementum advances, the gum recedes from the necks of the teeth, especially the labial surfaces, which, as a rule, become sensitive to thermal changes, particularly to cold. The teeth by degrees lose their firm hold in the alveolus, due to the absorption of the cementum and the socket. This enables us to introduce a probe, sometimes more than half-way between the alveolus and the root of the tooth, without pain. Pyorrhœa alveolaris is not uncommon in front teeth which have lost their proper antagonism, especially when either the upper or the lower jaw protrudes. As the disease proceeds toward the apex of the root the socket is destroyed, sometimes only on one side, but often in the entire extent of the root of the tooth. In such instances the pulp of the tooth often becomes devitalized, mostly without the knowledge of the patient. The affected teeth seldom are discolored, and I have seen instances where transillumination gave but negative results. When the inflammatory process has existed for a long time, granulation-tissue is formed, which usually absorbs portions of the root and the alveolus. A. Witzel holds the opinion that the granulations principally spring from the medulla of the alveolus. Such new formations may be seen around the cervical as well as the apical portion of the root, and always induce a rapid loosening of the tooth.

Subjective Phenomena.—Pyorrhœa alveolaris in its beginning usually is not noticed by the patient, and even in its later stages causes no pain. The patient complains, however, of an uneasy, annoying sensation in the teeth and jaws. There may be loss of appetite, although this can be attributed to constitutional causes as well as to the local disease. The teeth in advanced stages, even though quite loose, are tolerably comfortable in mastication so long as the roots have not been absorbed by granulations. When, however, this happens, the tooth becomes sensitive to pressure and percussion. Such a tooth, if subjected to mechanical violence, usually reacts by a painful *acute* attack of purulent diffuse pericementitis. Should the pulp of a tooth become devitalized in consequence of pyorrhœa alveolaris, the patient has no pain whatever from this source.

Differential Diagnosis.—Pyorrhœa alveolaris might be confounded with a deposition of salivary calculi, which in some instances gives rise to symptoms similar to those of true pyorrhœa alveolaris. The principal characteristic of pyorrhœa caused by salivary calculi is that it yields to local treatment in a comparatively short space of time, and usually does not return so long as the necks of the teeth are kept free from calculary deposits.

Another disease which might be mistaken for pyorrhœa alveolaris is chronic hyperplastic diffuse pericementitis, which sometimes is accompanied by a purulent inflammation. As the latter disease mostly occurs in devitalized teeth, and generally is confined to *one* tooth, the diagnosis becomes comparatively easy.

A process in many respects similar to the one under consideration is "*senile atrophy of the jaw-bones.*" This, as a matter of course, is found in old persons, although exceptionally we meet with it in middle age. The characteristic feature of this process is a gradual wasting of the alveolus, and, if the person is otherwise healthy, no pus will be visible around the necks of the teeth. The gums are generally of healthy appearance, although sometimes they may be slightly inflamed. In the early stage of senile atrophy of the jaws, the necks of the front teeth become denuded of their gums, first upon the labial surface. In the molars, especially the upper ones, the lingual surfaces are affected first, and we often see the lingual roots of these teeth entirely bare. The same atrophy is noticed after the extraction of the molars on one side of the jaw. The teeth in the opposite jaw having lost their normal antagonism, on account of the absorption of the alveolus, apparently elongate, and subsequently fall out. This process in a healthy person usually makes but little progress, especially when all or most of the teeth are present in the dental arch. When, on the contrary, the system is attacked by a chronic, wasting disease, we soon notice chronic purulent pericementitis, more or less pronounced, around the loose teeth. Almost the only characteristic of senile atrophy in this form is that the calculary deposits seldom are seen beneath the alveolar border. In such a complication, senile atrophy of the jaws exhibits the picture of pyorrhœa alveolaris, and yet senile atrophy combined with pericementitis, even though the system be impaired, yields to proper treatment. Such teeth, as a matter of course, are loose and will remain so, but they may be serviceable and be preserved for many years.

The prognosis of pyorrhœa alveolaris depending upon constitutional derangements is not altogether hopeless, provided the general disturbance can be combated, although, in most instances, when the calculary deposits have extended beyond the middle portion of the root, the saving of the tooth becomes doubtful. In such a case the prognosis is the worse the older the patient; while the disease, if occurring under thirty years of age, is mostly curable. When the disease has lasted for some time, granulation-tissue often arises, which, if situated around the neck of the tooth, and accessible to treatment, may not prevent the tooth from being saved. Should, on the contrary, granulomata develop at the apex of the root, the prognosis of the tooth becomes doubtful. Although we must admit that pyorrhœa alveolaris is a disease not always amenable to treatment, we ought not to sacrifice the teeth unless they cause trouble. The author not infrequently has seen teeth so loose that they might have been removed by the fingers, the calculary deposits besides being present more than half-way toward the apex of the root, and yet they have, under proper treatment, grown firmer in their sockets.

X. Chronic Purulent Circumscribed Pericementitis, so-called "Blind Abscess."—This form of pericementitis is mostly the outcome of repeated attacks of an acute non-purulent circumscribed pericementitis, more especially when due to constitutional derangements. It is also known to arise from foreign bodies, such as bristles of a tooth-brush, fine fish-bones, etc., when obtaining access into the pericementum. In a healthy person the presence of a foreign body in the pericementum usually leads to an acute inflammation, while in poorly-constituted patients such an irritation may lead to a chronic suppurative inflammation. It seems that the staphylococci introduced into the depth of a tissue cause suppuration easier in the latter than in the former instance.

Diagnosis.—Besides chronic purulent circumscribed pericementitis, there is often present chronic hyperplastic pulpitis, the more pronounced the longer the blind abscess has existed. In the beginning the abscess causes but little discomfort to the patient, except that occasionally the affected tooth is sensitive to thermal changes. From time to time the patient notices a swelling of the gum corresponding to the diseased portion of the pericementum. The swelling upon the evacuation of the pus soon disappears, and with it the tooth is comfortable, until another subacute attack sets in. These paroxysms of pain last from two to four days, while the intervals between the attacks may last from one to six months. The disease is met with both in sound and carious teeth, though the latter process in this form of pericementitis never extends to the pulp-chamber. The color of the affected teeth always is normal, and trans-illumination will yield but negative results. The tooth is somewhat loose in its socket, and quite painful to pressure, especially in the direction toward the inflamed portion of the pericementum. Cold water or the inhalation of cold air produces excruciating pains lasting from ten minutes to half an hour. Pressure upon the gum over the inflamed pericementum is painful, at the same time causing the oozing forth of pus from the abscess, the pus making its appearance between the neck of the tooth and the surrounding gum. Percussion upon the affected tooth is painful, and elicits a distinctly dull sound, especially when directed toward the inflamed portion of the pericementum.

Subjective Phenomena.—The pain in chronic purulent circumscribed pericementitis is principally due to pulpitis. In all cases that have come under my observation, chronic hyperplastic *pulpitis* was present, which by an additional irritation, such as an accidental hard bite or extreme thermal change, assumed an acute character. The pain is of throbbing character and excruciating. Articulation is impossible, because the tooth is raised in its socket. Upon attempting to open the pulp-chamber we find the dentine abnormally sensitive, often inducing a paroxysm of almost unbearable pain. Chronic purulent circumscribed pericementitis sometimes may be accompanied by a slight rise of temperature, which usually occurs toward evening.

Differential Diagnosis.—Chronic purulent circumscribed pericementitis may be confounded with acute purulent diffuse pericementitis. The principal characteristic of the former disease is that the tooth is of normal color and contains a living pulp, while the pulp of a tooth attacked by acute purulent diffuse pericementitis is always devitalized and in most instances discolored.

The prognosis of teeth affected by chronic purulent circumscribed pericementitis as such, would be quite favorable, if by some means we were able to extirpate the diseased pulp. Aside from the dentine being extremely sensitive to the action of the bur, the pericementitis renders the tooth painful to pressure, and consequently such teeth are usually lost.

XI. Chronic Purulent Apical Pericementitis.—Under this head I propose to describe a form of chronic abscess principally confined to the apices of the roots of the teeth. This disease is always the outcome of an acute or sometimes subacute non-purulent apical pericementitis, mainly depending upon the constitutional peculiarities of the patient. The better the constitution, the more acute and severe will be the pericementitis; on the other hand, the poorer the constitution, the less acute (subacute) and the more chronic the inflammatory process will be.

Diagnosis.—A tooth affected with chronic purulent apical pericementitis is somewhat loose in its socket, although the gum around the neck of the tooth is firmly attached and appears comparatively healthy. This disease most frequently occurs in teeth the pulps of which have been largely exposed and subsequently died from moist gangrene or chronic purulent pulpitis. The pus, therefore, has had an opportunity to escape from the abscess through the apical foramen, whereby the chronic inflammation usually remains limited to the apical portion of the root. The teeth usually are much discolored. The oral mucosa in the vicinity of the apex of the affected root may be slightly swollen and sensitive to pressure, or may appear normal. Percussion and pressure upon the tooth in the direction of the apex of the affected root always is more or less painful, and the former will elicit a distinctly dull sound. The principal characteristic of such teeth is that as soon as the opening of the pulp-canal becomes temporarily obstructed by particles of food or a piece of cotton, severe pain is the result. When a tooth attacked by chronic purulent apical pericementitis is extracted, we sometimes find attached to the apex of the root the abscess inclosed in a more or less spherical bag. In other instances the sac is torn in the extraction of the tooth.

Subjective Phenomena.—As long as the pulp-canal remains open and the pus is able to escape freely, chronic purulent apical pericementitis produces but little pain, though the tooth may be tender in mastication. Thermal changes applied to such teeth have no effect.

Differential Diagnosis.—The only disease with which chronic purulent apical pericementitis might be confounded is chronic purulent diffuse pericementitis. In the latter disease, however, pus usually is eliminated when pressure is applied upon the gum in the vicinity of the affected root. Besides, the gum in the latter disease never is attached to the neck of the tooth, and the obstruction of the pulp-canal by food or cotton usually will produce no trouble, whereas in cases of chronic purulent apical pericementitis such an obstruction is followed by severe pain.

The prognosis of teeth affected with chronic purulent apical pericementitis much depends upon the constitution of the patient and upon his toleration to pain. Another fact has to be taken into consideration,—viz, the condition of the apex of the root of the affected tooth. When the disease has existed for some time, granulation-tissue will arise, partially absorbing the root, whereby usually the tooth becomes lost. The prognosis of chronic purulent apical pericementitis may be expressed in short as follows: If the disease has not lasted long enough to affect the apex of the root, and we are able to destroy the so-called pyogenic membrane and afterward thoroughly disinfect and fill the pulp-canal, such a tooth may be saved. If, on the contrary, the end of the root has been absorbed by granulations, or the patient will not submit to the destruction of the pyogenic membrane, the tooth should preferably be extracted.

XII. Chronic Purulent Diffuse Pericementitis.—In most instances the disease under consideration originates from acute non-purulent diffuse pericementitis, or chronic purulent pulpitis. It may also develop after the death of the pulp by gangrene.

Diagnosis.—A tooth affected with purulent diffuse pericementitis is quite loose in its socket, and can be moved laterally as well as perpendicularly without causing much pain. Articulation, on the contrary, is always painful. The tooth usually is discolored, indicative of the devitalization of its pulp. The mucous membrane around the root of the affected tooth is more or less inflamed, tumefied, and soft to the touch. The color of the gum is dark red, often exhibiting a bluish ring around the neck of the tooth. The gum has lost its attachment to the neck, and often we are able to pass a fine probe between the tooth and the gum, even for some distance into the pericementum, without producing either hemorrhage or pain.

Pressure upon the gum with the point of the index finger is somewhat painful, and will always be followed by an evacuation of more or less pus. In advanced stages the affected tooth sometimes becomes extremely sensitive to pressure in one or more directions. This indicates that an absorption of the root, or a new formation of bone-tissue, either in the hyperplastic pericementum or upon the walls of the socket, is present. Percussion upon the crown of a tooth affected by chronic purulent diffuse pericementitis always is painful, and elicits the dullest of all sounds produced by percussion of teeth in the mouth.

Subjective Phenomena.—With the exception of pain in mastication, the patient experiences but little discomfort from a tooth attacked by chronic purulent diffuse pericementitis.

Differential Diagnosis.—The disease under consideration may be confounded with chronic hyperplastic diffuse, with chronic purulent apical pericementitis, with alveolar abscess, and with necrosis of the jaw-bones.

Chronic hyperplastic diffuse pericementitis can hardly be differentiated from chronic purulent diffuse pericementitis, especially since, in advanced stages, the former disease always is associated with the latter.

Chronic purulent apical pericementitis is characterized by the gum being closely attached to the neck of the affected tooth; while in chronic purulent diffuse pericementitis the gum always is found detached, emitting pus upon pressure. Alveolar abscess may be differentiated from chronic purulent diffuse pericementitis by the œdema of the face, which, in the majority of cases, is present in the former disease. Another characteristic of alveolar abscess is the fistula in the mucous membrane, communicating with the abscess, which never is found in chronic purulent diffuse pericementitis.

Necrosis of the jaw-bone is recognized by the denuded surface of the bone presenting a roughness when a probe is passed over it. Here we always find the periosteum more or less detached from the surface of the bone. In cases where the necrosis originated from chronic purulent pericementitis, it usually is limited to the surrounding alveolus of one tooth. When, on the contrary, the necrosis is of syphilitic or phosphoric origin, it may involve many teeth simultaneously, although in such an instance the teeth may still be alive.

The prognosis of teeth affected with chronic purulent diffuse pericementitis mainly depends upon the constitution of the patient and the stage to which the disease has advanced. As long as it is not associated with diffuse hyperplastic pericementitis, and the constitution of the patient is not impaired, the prognosis is fair. The presence of hyperplastic new formations in the pericementum is indicated by pains when even slight pressure is brought to bear upon the tooth. In such cases it ought to be removed. On the other hand, when granulations are absent and the pulp-canal is carefully disinfected, and, after the cessation of the formation of pus, is thoroughly filled, such a tooth might be saved.

XIII. Chronic Alveolar Abscess.—Under the foregoing heads I have described the morbid changes in the pericementum alone; in the following I propose to dwell upon the secondary processes subsequent to pericementitis.

When purulent pericementitis has lasted for some time, the inflammation spreads to the neighboring bone-tissue, which process, though secondary to pericementitis, must be regarded as a disease of the jaw-bones. Among the forms of inflammation of the root-membrane principally causing chronic alveolar abscess, I would mention chronic purulent diffuse and chronic hyperplastic pericementitis.

Diagnosis.—In the early stage of a chronic alveolar abscess the mucous membrane over the affected root is considerably swollen and softened, similar in appearance to that found in chronic purulent diffuse pericementitis. In later stages, almost invariably a fistulous communication with the abscess is present, due to an ulcerative destruction of the mucosa. In quite chronic cases the fistula becomes closed from time to time, thus producing the formation of a parulis (so-called "gum-boil"). This formation is characteristic of chronic alveolar abscess when the periosteum is neither much thickened nor detached from the bone. Should the pericementum be hypertrophied or detached, no gum-boil is found, the opening of the fistula is not obstructed, and the disease has advanced to a further stage,—*i.e.*, periostitis, or necrosis of the jaw-bone. In slowly-progressing cases we sometimes see around the parulis a growth of granulation-tissue, in shape and size of a pea. In rare instances, especially in the teeth of the upper jaw, the fistula does not break open through the mucous membrane, but the pus is evacuated around the neck of the affected tooth. Exceptionally the fistulous opening is not seen in the vicinity of the affected root, but some distance from it, in which instance it may be difficult to find the tooth. It occurs, though rarely, that the fistula of one of the upper front teeth opens at the border of the hard palate. The fact that the disease under consideration always is caused by a devitalized tooth will assist us in clearing the diagnosis. Furthermore, pressure and percussion upon the affected tooth are always sensitive, though such a tooth may not be elongated or loose in its socket. In quite chronic cases, where the granulations have absorbed portions of the root and the alveolus, the tooth is markedly sensitive to pressure and percussion. In such cases we not infrequently find the alveolar process of both neighboring teeth lost, which loss often can be distinctly detected by the point of thei ndex finger.

Subjective Phenomena.—Chronic alveolar abscess, in its incipient stage, when osteitis sets in, is accompanied by drawing pains, and sometimes by fever. During this period, which usually lasts from one to three days, the tooth is sensitive to the touch and to mastication. In time the process assumes a less acute course, and when the gum-boil becomes established, the patient suffers no more pain. Only the rupturing of the parulis, from time to time, indicates the existence of a chronic alveolar abscess.

Differential Diagnosis.—In most instances a chronic alveolar abscess is easily recognized. Where no fistulous opening is present, it might, however, be confounded with chronic purulent diffuse or circumscribed pericementitis, as well as chronic purulent hyperplastic pericementitis. Hyperplastic and diffuse pericementitis are so similar to a chronic alveolar abscess without a fistula, that a correct differentiation is not always possible. Chronic purulent circumscribed pericementitis, however, is characterized by the living pulp the tooth mostly contains, while chronic alveolar abscess occurs only in devitalized teeth.

The prognosis of teeth affected with chronic alveolar abscess, on an average, is good, especially in cases which have not existed long enough to develop granulations at the end of the root. The rule here, as in the treatment of teeth affected with chronic purulent pericementitis, is that so long as the root has not been absorbed the tooth can be saved. The success of the treatment, however, depends upon the ability of the operator and the form and accessibility of the pulp-canal of the affected tooth. If the pulp-canal can be thoroughly disinfected and filled, and no filling-material has been pushed through the apical foramen of the root, the tooth is usually saved.

XIV. Cementitis and Eburnitis. Inflammation of the Cementum and Dentine.—As already mentioned, wherever a chronic inflammatory process has existed for some time, granulation-tissue develops, leading to a gradual destruction of the root of the tooth, by cementitis and eburnitis. These processes, under the microscope, are characterized by bay-like excavations in the hard tissues, often filled with multinuclear protoplasmic bodies. In some instances even new formations of bone are met with in the adjacent tissues.

Diagnosis.—To the naked eye the roots of teeth affected by cementitis and eburnitis present deep and irregular cup-shaped excavations, between which sharp projections are left. When pressure is exerted upon the crown of a tooth affected by cementitis and eburnitis, the sharp projections irritate the adjacent pericementum, thus causing more or less pain. The gum in the vicinity of the affected root is in some instances inflamed, in others normal, depending upon the condition of the pericementum.

The only subjective phenomenon of cementitis and eburnitis is indeed, as mentioned before, that pain is produced on pressure upon the tooth.

Differential Diagnosis.—A diagnosis of this disease cannot be made with any degree of certainty until the tooth has been extracted.

The prognosis of teeth affected with cementitis and eburnitis always is unfavorable, since the sharp projections of the denuded root continually keep irritating the pericementum. Such teeth are usually lost.

XV. Periostitis, Osteitis, and Osteomyelitis.—As these diseases usually are associated with, and the outcome of, purulent pericementitis, I shall consider them under one head. Occasionally they occur in consequence of mechanical violence, —*i.e.*, by a hard blow; in difficult eruption of the wisdom-teeth, especially the lower ones; or in tearing of the gum in extracting badly-decayed roots. These diseases always arise by an infection, sometimes accomplished by the use of septic instruments or unclean tooth-picks, pushed under the gum.

Diagnosis.—The inflammatory process attacking the periosteum extends over the bone, either in the form of osteitis, osteomyelitis, or necrosis. Periostitis in the beginning always is acute, and causes swelling of the mucous membrane, and sometimes considerable œdema of the lip and cheek. When this occurs in the lower jaw, the swelling soon involves the submaxillary gland, and often spreads down to the shoulder. Together with the periostitis, usually there is a swelling and rigidity of the muscles of mastication, whereby the patient is unable to open the mouth. Periostitis, when a sequel of pericementitis, mostly is preceded by osteitis and osteomyelitis, in which case the inflammation first attacks the bony socket, before its periosteal covering becomes involved. In cases of traumatic origin, however, as a rule, the periostitis is the primary process, while the osteitis, osteomyelitis, or necrosis are secondary occurrences. Periostitis in an acute stage may exist alone; but subacute or chronic cases are always accompanied by more or less osteitis, osteomyelitis, or necrosis of the jaw-bones. In the majority of instances an inflammation of the alveolar periosteum is the result of a devitalized tooth, which may be easily recognized by its dark color. The extent of the area of the affected alveolus greatly varies. In some cases it is only as large as a pin's head, while in others the process may involve the alveolar processes of four or five teeth in a comparatively short space of time. When purulent periostitis, osteitis, or osteomyelitis are present, as a rule, one or several fistulous openings are seen in the gums. Sometimes, however, the pus is evacuated along the necks of the teeth. In quite severe and chronic cases, especially those of the lower jaw, the pus, after perforating the bone, makes its appearance on the outer surface of the skin. When the diseases under consideration originate in consequence of difficult eruption of the lower wisdom-teeth, the swelling and the formation of pus may be copious, especially in acute cases, while those of a more chronic type seldom exhibit much swelling or pus. The gum over the affected periosteum usually is spongy to the touch, and, according to the stage the inflammatory process has advanced, is characterized by more or less redness and heat. Not infrequently periostitis, osteitis, and osteomyelitis, when present in the upper jaw, extend into the antrum, or even the nasal cavities, on which emergencies I shall dwell more fully in a separate chapter. When chronic pericementitis becomes diffuse, it may be accompanied by the formation of fistulæ and abscesses in the neighboring tissues. The writer has seen patients who, in consequence of a neglected chronic alveolar abscess, suffered from secondary abscesses in several places of the neck, near the clavicle. There are even fatal cases on record in which the pus found its way into the mediastinum, producing secondary abscesses, purulent pleuritis, or œdema of the lungs.

Subjective Phenomena.—In periostitis, osteitis, and osteomyelitis, much depends upon the constitution of the individual. The better the general health of the patient, the more acute is, as a rule, the inflammatory process, and the greater will be the suffering, especially in diffuse inflammation. In such instances these diseases always are accompanied by more or less fever and other derangements of the system, the more severe the greater the number of deep-seated abscesses formed in the neighborhood of the inflamed parts. The majority of cases of periostitis, osteitis, and osteomyelitis, however, do not become diffuse, but remain localized to a comparatively small area. Then, should the trouble be caused by pericementitis, the patient experiences but little pain from the periostitis, while osteitis and osteomyelitis are accompanied by excruciating pains. As soon, however, as the alveolar process is perforated by the pus the pain subsides, and periostitis, in itself not very painful, as stated before, takes issue.

Differential Diagnosis.—Periostitis in either its localized or diffused form cannot easily be mistaken for another disease, while osteitis and osteomyelitis may sometimes be confounded with necrosis of the jaw-bones, the more so since it mostly is associated with the former. The distinguishing peculiarities of necrosis are the roughness and hardness of the exposed surface of the bone to the probe. The periosteum is detached, and between it and the bone a considerable amount of pus is continually formed, freely escaping upon pressure. Inflamed bone appears softened to the touch of the probe; its surface, when exposed, looks red, its periosteum is hypertrophied and more or less firmly attached to the diseased bone.

Prognosis.—Periostitis, osteitis, and osteomyelitis, occurring in consequence of mechanical violence, usually yield to antiseptic treatment in a comparatively short space of time, and without the loss of teeth. When, however, these diseases are due to purulent pericementitis, the loss of the tooth, together with a portion of the alveolar process, cannot be avoided. When secondary abscesses have formed in the region of the neck or the mediastinum, these diseases become quite serious, as a rule, and sometimes even endanger life.

XVI. "Lymphadenitis," Inflammation of the Lymph-Ganglia.—The name "lymphadenitis," though generally used, is erroneous, since it means inflammation of a lymph-gland, whereas the lymph-follicles and lymph-ganglia are not glands, lacking epithelial structure altogether. Inflammation of the lymph-ganglia is most common in the submaxillary region, always due to a transmission of infectious material through the lymph-vessels into the lymph-ganglia. There are persons who, upon the slightest non-purulent inflammation of the pulp or the pericementum, react with a swelling of the submaxillary ganglia. Purulent pulpitis and pericementitis, with all the inflammatory complications dependent upon them, are invariably accompanied by a swelling and hardening of the lymph-ganglia. Gangrene of the pulp is prone to cause this trouble. All this holds good only for infectious diseases of the teeth of the lower jaw, while those of the upper jaw but rarely affect the lymph-ganglia in the submaxillary region. It seems that this disease is more common in youths under ten years than in persons more advanced in age. In adults it frequently occurs during difficult eruptions of the wisdom-teeth, or after their extraction. In some instances lymphadenitis makes its appearance after an attempted extraction of a tooth or a root, in which case, however, the symptoms never are severe.

Diagnosis.—In the beginning of the process the submaxillary ganglia swell and become hard. The covering skin is rendered tense and hot, and the enlarged knot immovable. The slightest pressure upon it is painful. The swelling in mild cases attains the size of a walnut, while in severer ones it may reach the size of a man's fist or more. There is great rigidity of the muscles of the jaw, so much so that the mouth can only be opened by means of instruments. The principal characteristic of this disease is that there usually are no fistulous openings present in the gum. Although, as a rule, the inflammatory infiltration soon abates, in rare instances the ganglia suppurate, indicated by a red spot upon the skin covering the ganglia, and by the fluctuation. These symptoms usually are accompanied by more or less fever.

Subjective Phenomena.—In the beginning of the process the patient experiences but little pain, unless something comes in contact with the swollen ganglia. In the milder forms this disease does not cause pain, but only discomfort; while the severer cases, accompanied by fever and the formation of an abscess, are quite distressing. Real pain commences as soon as the submaxillary ganglia verge to suppuration.

Differential Diagnosis.—Taking into consideration the subjective symptoms, and what has been stated concerning the diagnosis of the disease in question, it cannot easily be mistaken for another disease.

Prognosis.—In lymphadenitis much depends upon the constitution of the patient. Otherwise healthy persons, when attacked by the disease, seldom suffer much, nor are the ganglia apt to suppurate except in a so-called lymphatic constitution.

Some very acute cases may become annoying, more by the protracted swelling of the neck and the disfigurement, often lasting for weeks, than others in which suppuration has taken place.

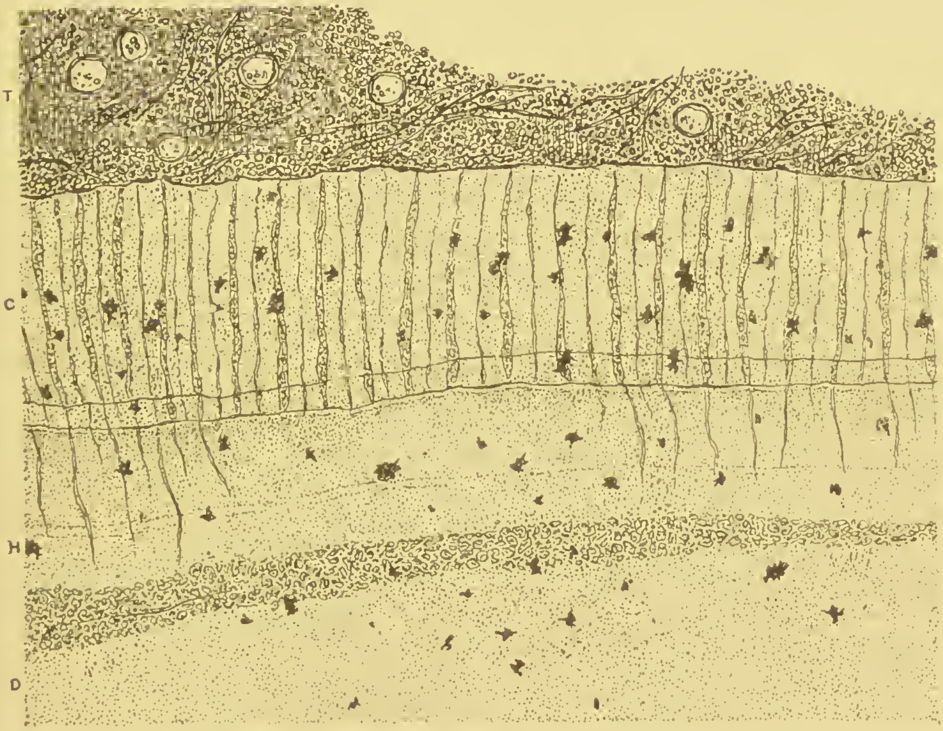
CHAPTER XXXIX.

MORBID ANATOMY OF PERICEMENTITIS.

According to the severity of the irritation, and the constitutional peculiarities of the individual, pericementitis presents itself as acute or chronic, either of which may be non-purulent or purulent. Acute pericementitis is not infrequently confined to the region of the neck of the tooth. As in any other acute inflammatory process, it may issue in a hemorrhage, especially in so-called hæmatophiles or bleeders, who upon the slightest injury bleed profusely, both from open wounds at the surface of the body and from a comparatively slight inflammatory process. such as ulitis or marginal pericementitis. In my collection of microscopical specimens, which embraces thousands of objects from pathological teeth, are several obtained from the neck of a tooth in which I observed the presence of a large number of clusters of hæmatoidin crystals in the neck layer of the cementum as well as in the subjacent so-called granular layer of the dentine. (See Fig. 230.) This condition may be termed *apoplexy* or *hæmorrhagic infarctus* of the hard tissues of the teeth. In my judgment, it is impossible to explain the presence of hæmatoidin in the cementum and the dentine without a previous suffusal of these tissues with blood. The fact that the cementum of the neck is rich in protoplasmic bodies and the granular layer of the subjacent dentine rich in living matter, arranged in the shape of a coarse reticulum, affords an explanation of this remarkable condition.

Acute Non-Purulent Pericementitis, in its mildest degree, with lower powers of the microscope, is recognizable by the presence of nests, filled with medullary elements, in the midst of the connective-tissue bundles. The shape of these nests is, as a rule, oblong, corresponding to the longitudinal direction of the connective-tissue bundles, or roundish, in accordance with the cross-section of bundles. The scantier these nests, the milder is the inflammatory process. With high magnifying powers of the microscope we learn that the earliest stage of the inflammation consists in a transformation of the connective-tissue fibers into protoplasm. With the knowledge of the normal structure of the pericementum we are enabled to comprehend that a mere liquefaction of the basis-substance is sufficient for the reproduction of the protoplasmic condition of the basis-substance. Such a reproduction occurs in the shape of streaks in the midst of a bundle, independently of the original protoplasmic bodies,—the formerly so-called connective-tissue cells. (See Fig. 231.)

Fig. 230.

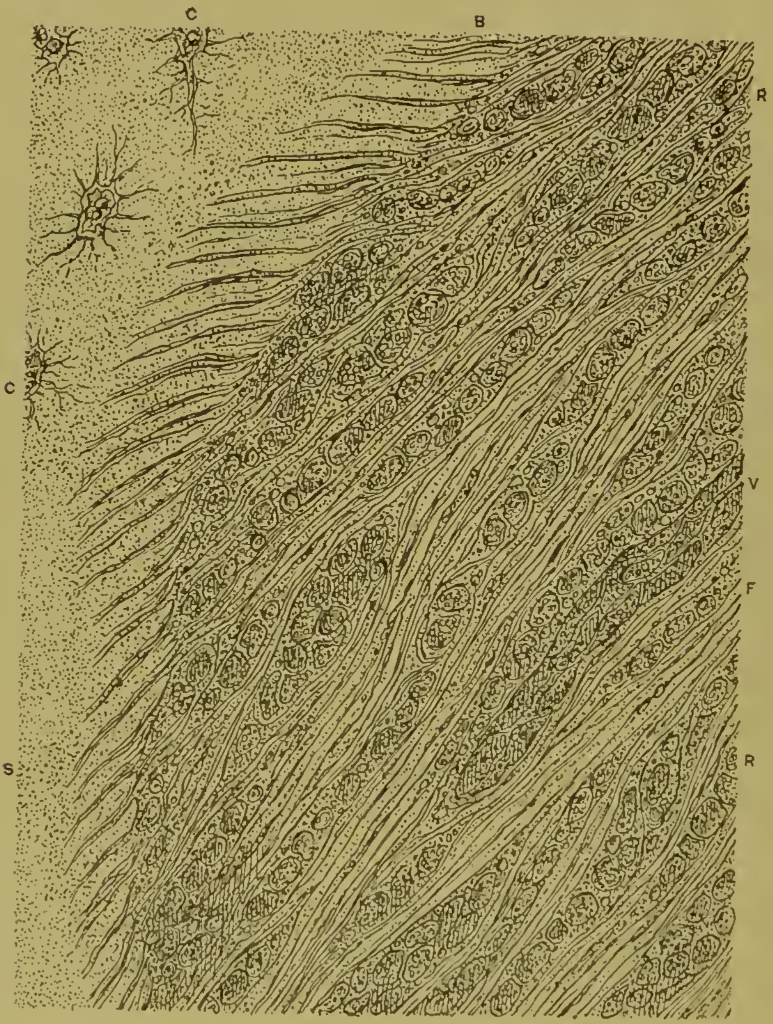


Clusters of Hæmatoidin in the Cement and Dentine of the Neck.

T, decalcified tartar; *C*, cementum of neck with numerous clusters of hæmatoidin; *D*, granular dentine of neck; *H*, clusters of hæmatoidin in dentine. Magnified 500 diameters.

According to the spindle shape of the elementary fields of the basis-substance, spindle-shaped protoplasmic bodies have appeared, wholly identical with the normal protoplasmic bodies within the fibrous connective tissue. All these bodies are separated from one another by light rims, and connected with each other by the delicate threads of living matter traversing those rims. The finely-granular newly-appeared protoplasmic bodies soon afterward become coarsely granular, which means that the living matter therein has increased in bulk. A liquid exudation as such is never visible under the microscope, but we infer its presence both from the liquefaction of the basis-substance and the increase of living matter, which latter can only be due to an increased afflux of nourishing material. These changes take place in the newly-appeared as well as in the original protoplasmic bodies, the nuclei of which invariably

FIG. 231.



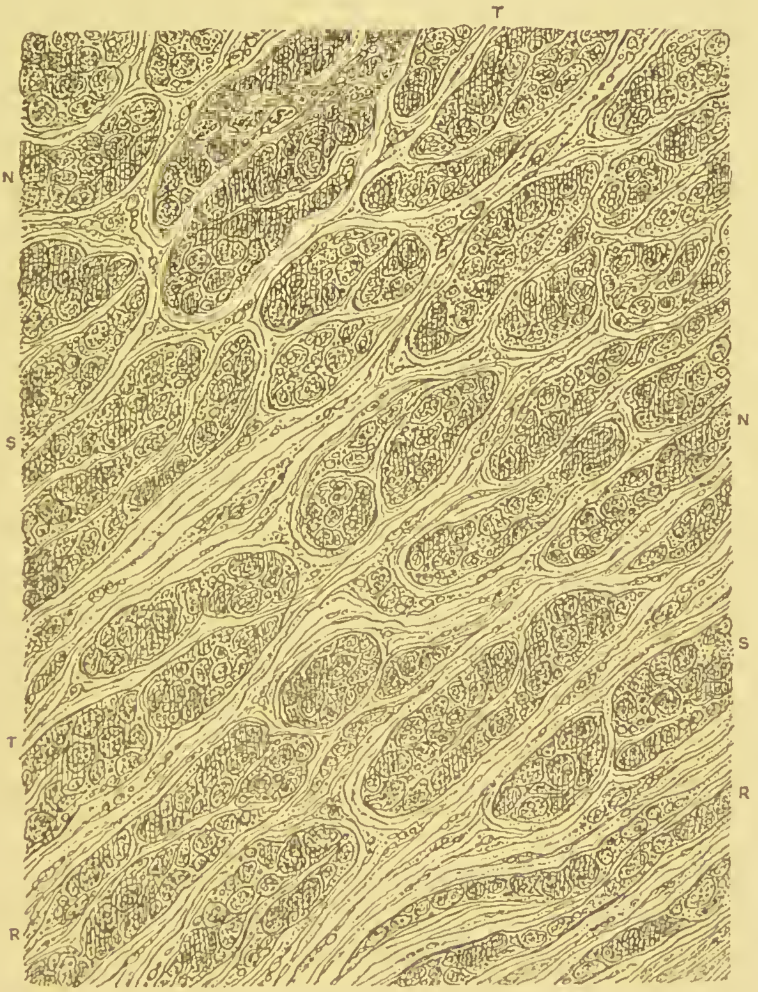
ACUTE PERICEMENTITIS OF A MODERATE DEGREE.

F, fibers of pericementum unchanged; *R*, *R*, rows of inflammatory or embryonal corpuscles; *V*, capillary blood-vessel obliterated; *B*, bundles of pericementum implanted into cementum; *C*, *C*, cement-corpuscles; *S*, basis-substance of cementum. Magnified 500 diameters.

become shining, homogeneous, and enlarged, owing to the same cause which led to the enlargement of the points of intersection of the reticulum of living matter.

We see next that a number of granules—the points of intersection of the reticulum—have increased in size to such an extent that they resemble small nuclei, and from these foci new protoplasmic elements are formed, partly shining and homogeneous, partly reticular in structure. After the originally solid lumps of living matter have split into a reticulum, many of the newly-formed elements contain solid nuclei. All elements are uninterruptedly connected with each other by delicate threads

Fig. 232.



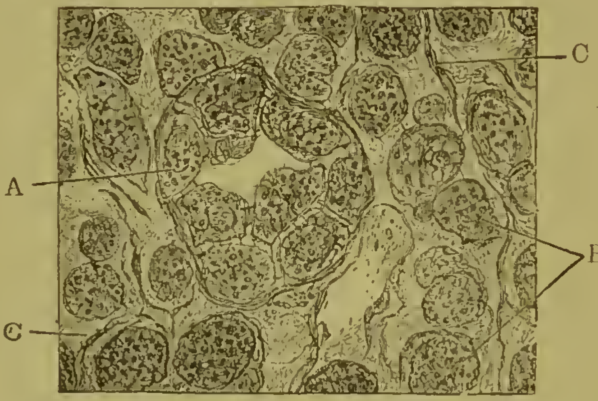
Intense Pericementitis, verging on Suppuration (Zone 2) of Fig. 242.

T, T, tracts of fibrous connective tissue much reduced in bulk; *N, N,* nests of inflammatory corpuscles crowded with staphylococci; *S, S,* clusters of staphylococci; *R, R,* rows of inflammatory corpuscles in broad tracts of fibrous connective tissue. Magnified 500 diameters.

of living matter. Thus, the inflammatory infiltration is established at first in the shape of scattered nests, the centers of which correspond to the capillary blood-vessels. In later stages almost the whole amount of the connective tissue is transformed into medullary elements to such a degree that only scanty bundles of the original connective tissue are left. (See Fig. 232.)

The changes in the wall of the capillary blood-vessels are of considerable interest. Doubtless the largest accumulation of the inflammatory elements takes place in the immediate neighborhood of the blood-vessels, for in the midst of many nests capillaries can be traced. We readily understand that in the immediate vicinity of the source of nutrition the inflammatory process must be the liveliest. This fact has been taken up as an argument by those who assert that the inflammatory nests are altogether due to an emigration of colorless blood-corpuscles. I am strongly opposed to this opinion, because my observations show that the majority of the inflammatory elements are originally connected with one another by delicate threads, therefore representing a tissue. The endothelia of the capillaries share in the inflammation, by being transformed into coarsely-granular, irregular protoplasmic bodies, which, by division, also produce new medullary elements, partly nucleated, partly devoid of nuclei. By the new formation of inflammatory elements from the endothelia, the capillary is first considerably narrowed in caliber, and afterward completely obliterated. (See Fig. 233.)

Fig. 233.



Inflamed Pericementum in an Early Stage.

A, capillary blood-vessel, the endothelia of which are coarsely granular and proliferating: *B*, medullary or inflammatory elements, imbedded in a finely-granular basis-substance: *C*, *C*, spindle-shaped elements. Magnified 1000 diameters.

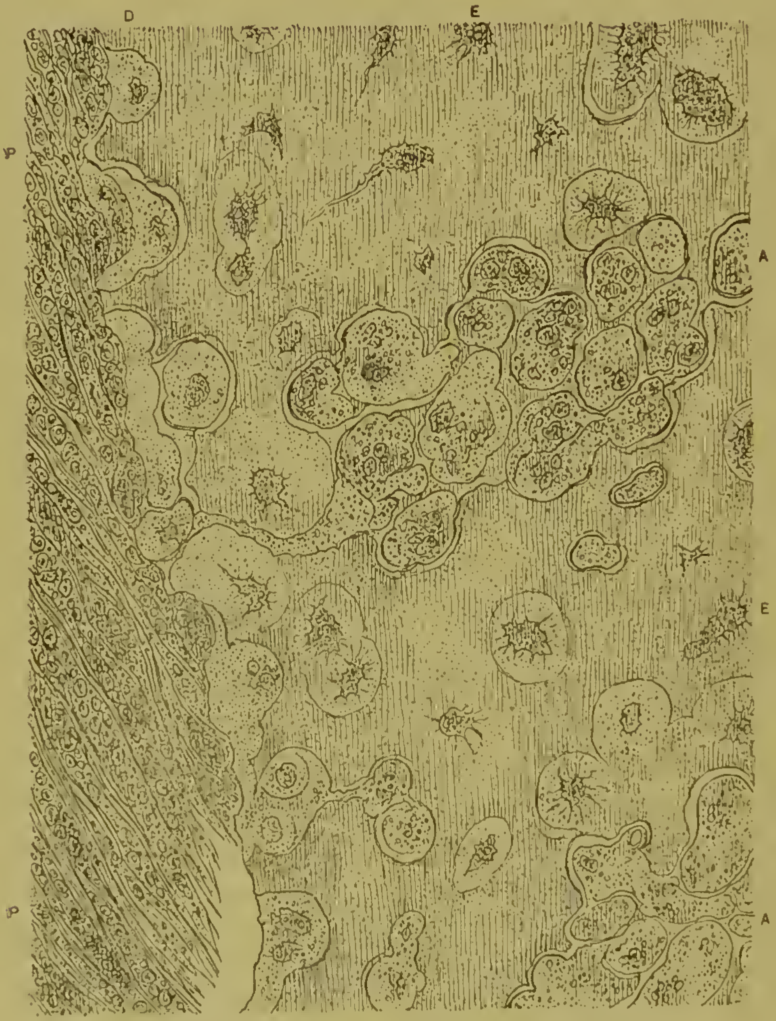
An exuberant growth of the endothelia will, as a rule, result in the destruction of the capillaries by suppuration, and will probably give rise to formations which I shall presently describe.

In most of my specimens of inflamed pericementum I have met with a singular formation. A number of medullary elements coalesce into globular masses, greatly varying in size, and in some instances surrounding a central polyhedral space, evidently made by the compression of the former blood-vessel. The globular masses are either composed of medullary elements, shining, homogeneous, and split into smaller lumps of living matter, or they are continuous masses of a coarsely-granular protoplasm in which varying numbers of nuclei are seen. There is scarcely any doubt that the latter formations have arisen from the former ones through confluence of the single medullary elements. On the boundary very often concentric layers of round or spindle-shaped, finely-granular elements are present. In specimens stained with a solution of chloride of gold the concentric layers are of a pale violet, while the protoplasmic masses inclosed therein exhibit a dark-purple color. Formations of this kind are well known in inflamed periosteum and medulla of bone; they have been termed myeloplaxes, myeloid bodies, giant-cells, etc. All the well-known hypotheses as to their significance disagree with what I have seen,—viz, the formation of territories of bone-tissue from these clusters.

My specimens show plainly that in the so-called plastic inflammation of the pericementum all inflammatory elements remain connected with one another, and thus represent a medullary, embryonal, or indifferent tissue. In slight degrees of inflammation the morbid process may yield to what has been termed "the resolution of inflammation." Nothing is required but the re-formation of the basis-substance, and the normal condition is re-established, sometimes so completely that no trace of the former inflammation is noticeable. More severe forms of plastic pericementitis, or repeated recurrences of the inflammatory process, will result in a new formation of the connective tissue, the so-called hyperplasia. Higher degrees of plastic pericementitis are invariably accompanied by inflammation of the gum, the cementum, and the bony alveolus.

Cementitis is shown under the microscope by the presence of bay-like excavations on the periphery of the cementum, and sometimes also beneath the surface. These excavations are filled with medullary elements or multinuclear protoplasmic bodies. On an average, the excavations are deeper and more numerous in proportion to the intensity of the original inflammatory process. To their presence is due the peculiar corroded appearance of the cementum in teeth extracted during an attack of pericementitis. (See Fig. 234.)

FIG. 234.

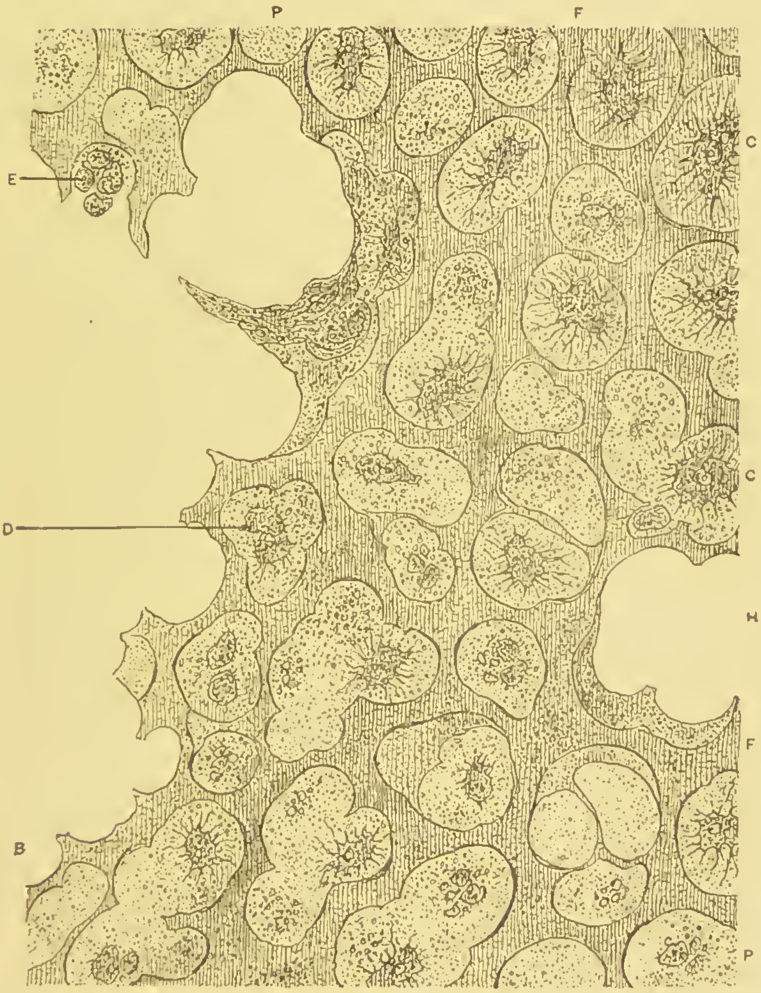


INTENSE ACUTE CEMENTITIS AND PERICEMENTITIS.

P, pericementum much inflamed; P^1, inflamed pericementum detached from cementum; *D*, dissolution of lime-salts in territories along the border of cementum; *A*, *A*, advanced reduction of cementum; *E*, *E*, enlarged cement-corpuscles. Magnified 500 diameters.

Osteitis of the bone of the alveolus is manifested in its incipient form by a dissolution of the basis-substance of the bony tissue, in the shape of bay-like excavations, corresponding to the territories of the bone-tissue. Within the decalcified territories coarsely-granular bone-corpuscles are seen, many of which are distinctly enlarged, sending forth numerous bifurcating offshoots. The territory itself is reduced to its protoplasmic condition, indicated by a fine and uniform granulation. In many places, however, clusters of coarse granules are seen, some of which have considerably increased in size, approaching that of medullary corpuscles, the inflamed bone thus appearing to be provided with far more bone-corpuscles than the normal bone.

Fig. 235.

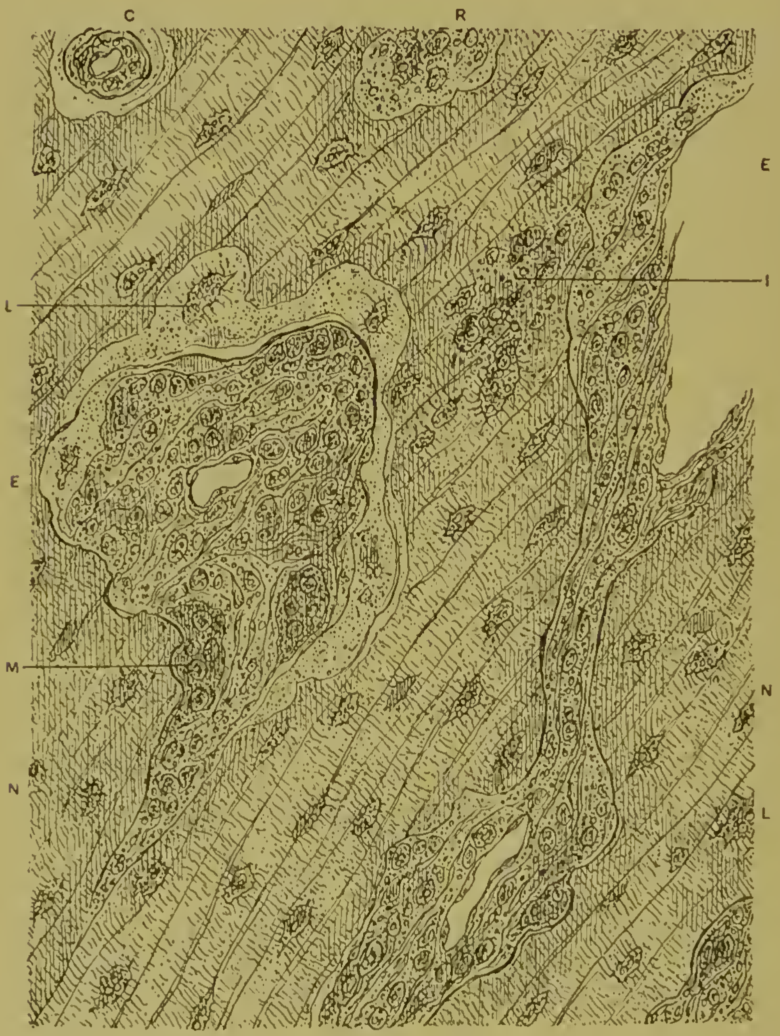


Incipient Osteitis of Alveolus. Dissolution of Lime-Salts. Reappearance of Territories.

F, still calcified framework at the borders of the territories; *C*, *C*, enlarged and coarsely-granular bone-corpuscles; *P*, *P*, reappearance of protoplasm within the territories; *E*, cluster of embryonal or inflammatory corpuscles; *D*, divided bone-corpuscle; *B*, empty bays, the inflammatory corpuscles dragged away; *H*, large empty bay, a so-called Howship's lacuna. Magnified 500 diameters.

This appearance is due partly to the enlargement of the old bone-corpuscles, partly to their splitting up into two or more protoplasmic bodies, and partly to the formation of new protoplasmic bodies. If the basis-substance melts completely, the entire existing bone-tissue is rendered protoplasmic, and by a new formation of medullary corpuscles from the living portion of the protoplasm medullary or inflammatory corpuscles arise filling the bay-like excavations, which have been originated by a fusion of the decalcified territories. Such bay-like excava-

Fig. 236.



Acute Osteitis in Alveolar Wall.

N, N, normal bone-corpuscles; *R*, territory reduced to protoplasm: *I*, bone-corpuscles increased in size and number; *L, L*, enlarged bone-corpuscles; *E, E*, medullary spaces much enlarged; *C*, normal medullary canal; *M*, multinuclear protoplasmic body. Magnified 400 diameters.

tions appear empty when specimens made from dry bone are examined, or if, in cutting the section, the medullary tissue is dragged away. They are known to pathologists as Howship's lacunæ. (See Fig. 235.)

When intense acute inflammation begins in the bony socket of the alveolus, the image under the microscope is somewhat different. No regular territorial decalcification takes place, but a rapid dissolution of the lime-salts in circumscribed nests occurs independently of Haversian canals. The previous bone-corpuscles and the living matter spread throughout the basis-substance of the bone lead to the rapid appearance of inflammatory or medullary corpuscles, either scattered singly in a myxomatous basis-substance or in clusters termed myeloplaxes. In the center of such an inflammatory nest, as a rule, a newly-formed capillary blood-vessel makes its appearance. At the periphery of the inflamed nest decalcification is indicated by more or less crescentic fields, imperfectly marked as to territory, such as we frequently see in the developing bone-tissue of embryos between the third and sixth months of intra-uterine life. The decalcification invades the bone-tissue diffusely, as we may infer from the fact that we see many enlarged and split-up bone-corpuscles without the reappearance of territories. In a thoroughly-calcified basis-substance such changes of the bone-corpuscles would be impossible. (See Fig. 236.)

This process is invariably combined with osteomyelitis, and the result of both processes is the transformation of the hard bony tissue into a soft medullary or inflammatory tissue. In some of my specimens of osteitis this change is exhibited to a very high degree, so that only small islands of bony tissue are left as remnants of the former wall of the alveolus.

Chronic Hyperplastic Pericementitis.—An intense plastic pericementitis, or repeated attacks of a so-called subacute inflammatory process, will lead to a new formation of connective tissue, cementum, and bone. New formations due to a distinct inflammatory process are termed hyperplasia or hypertrophy, in distinction from those new formations that arise without prominent inflammatory symptoms and are generally termed "tumors."

Hyperplasia of pericementum occurs whenever a large number of inflammatory elements are newly formed and remain in connection with one another, thus not ceasing to be a tissue.

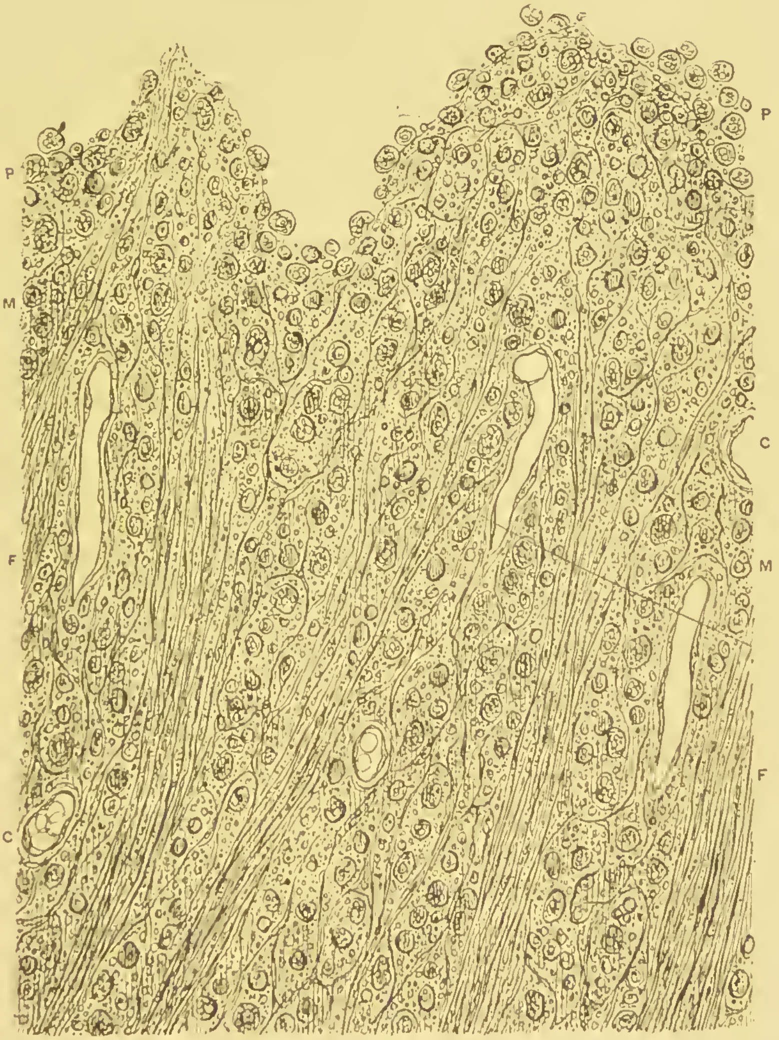
The inflammatory elements in certain districts become elongated, and, after having split into narrow spindles, are transformed into a solid basis-substance, which means a new formation of connective-tissue bundles. Such bundles differ from those of normal pericementum in their greater density and their very irregular arrangement. Hypertrophied pericementum is occasionally augmented in its entire bulk, and is built up of coarse bundles of connective tissue, between which, in the earlier stages of the hyperplastic process, more or less numerous nests of inflammatory elements are still seen. In other instances, the entire pericementum is transformed into a dense cicatricial connective tissue, whose bundles are very small, and, by crossing one another in all directions, produce a feltwork. Hyperplastic pericementum, as a rule, holds fewer blood-vessels than the normal.

Sometimes scattered nests of the inflammatory elements exhibit a high refracting power, which evidently is due to a deposition of lime-salts in them, the so-called calcification. This process is entirely different from ossification, though the former apparently precedes the latter. Scattered nests of inflammatory elements may be transformed also into clusters of fat-granules, which are recognizable by their peculiar refracting power, and by remaining unstained by either carmin or chloride of gold. Irregularly-distributed fat-globules are very often seen in hyperplastic pericementum. Whether these globules are identical with the original fat-globules in normal pericementum, or are formed after the inflammatory process has abated, I am unable to say.

Localized hyperplasia of the pericementum is sometimes observed at the neck of the tooth, in the shape of rather broad nodules, either pediculated or sessile, freely vascularized, and therefore of a deep-red color to the naked eye. The tissue of such a nodule, under the microscope, appears as a combination of fibrous and myxomatous connective tissue, richly supplied with capillary blood-vessels. (See Fig. 237.)

Nodules of this type are allied to granulation-tissue, the admixture of fibrous bundles being attributable to the original fibrous structure of the pericementum. Such nodules are prone to penetrate the cementum to varying depths. They cause the appearance of pits in the cementum of the neck of the tooth as well as the roots. Often they are transformed into pus at their surface, though suppuration is seldom profuse in this form of marginal pericementitis. Intense suppuration, combined with formations of myxomatous granulomata, is of not infrequent occurrence along the root, leading to an almost complete pitted absorption of the roots of the affected teeth. This process is invariably accompanied by intense cementitis and eburnitis.

FIG. 237.



HYPERPLASTIC MYXOFIBROUS PERICEMENTUM GRANULOMA AT THE NECK OF A MOLAR.

F, F, remnants of bundles of fibrous connective tissue; *M, M*, myxomatous granulation-tissue between the fibrous bundles; *C, C*, capillary blood-vessels; *P, P*, zone of suppuration. Magnified 500 diameters.

New formation of cementum is observable in two forms: either as re-formation in the bay-like excavations, or as a new formation on the outer surface of the cementum.

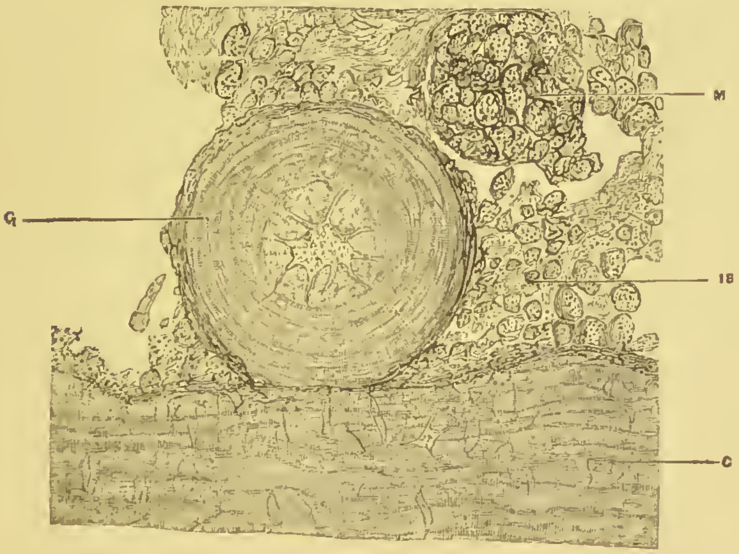
Re-formation of the cementum is always characterized by a deposition of lime-salts in the territories of the cement-corpuscles, previously dissolved by the inflammatory process. The bay-like excavations remain unchanged in their configuration, even after new cementum has formed. The difference between normal and newly-formed cementum is that in the latter cement-corpuscles are larger, more numerous, and irregular. In the basis-substance we not infrequently recognize the inflammatory elements (osteoblasts), the infiltration of which, first with a gluey basis-substance, afterward with lime-salts, has caused the new formation of cementum. In the cementum of both the neck and the root I have met with such sharply-circumscribed islands of newly-formed cementum, apparently with no connection with the outer surface. Nay, in some of my specimens such an island has formed in the cementum, covering the neck of the tooth, and, while the latter shows a normal structure, and is devoid of cement-corpuscles, the newly-formed cementum penetrates the dentine deeply, and exhibits a large number of irregular cement-corpuscles.

The inflammatory new formation on the surface of the cementum appears in the shape of either a continuous layer of cement-tissue, distinctly bounded toward the normal cementum, or jagged on the outer surface, with manifold elongations and erosions, filled with newly-formed connective tissue. Sometimes relatively large globular formations appear on the outer surface of the cementum as the result of pericementitis.

There are globular bodies in connection with the cementum by means of a pedicle, which closely resemble those in the pulp-cavity attached to the dentine. These peculiar formations exhibit a distinctly concentric lamination. They are surrounded by a layer of spindle-shaped medullary elements, and hold in their centers a radiating protoplasmic mass, resembling a bone-corpuscle. As to their origin, there can be scarcely any doubt that they arise from clusters of medullary elements or multinuclear protoplasmic bodies as above described, one of which is seen in Fig. 238, in the immediate neighborhood of the globular formation. We readily understand that a transformation of the medullary elements into bony basis-substance will lead to the formation of a laminated cement-globule; the difficulty is only to understand the origin of the central protoplasmic body. Perhaps this body is a former blood-vessel solidified, the like of which we can often trace in the midst of a multinuclear protoplasmic cluster. All new formations on the surface of the cementum caused by an inflammatory process may be properly denominated "exostoses of the cementum."

I have repeatedly seen true bony new formations in hyperplastic pericementum. They appear in the shape of irregular islands or elongated spiculæ within the fibrous connective tissue, sometimes so near to the cementum that no doubt is left about their formation in the midst of the pericementum, independently of the bony alveolus. These formations bear a close resemblance to embryonal bone,—viz, contain a large number of irregular bone-corpuscles, with broad offshoots, and a relatively small amount of bony basis-substance.

FIG. 238.



GLOBULAR BODY. RESULT OF PERICEMENTITIS.

G, concentrically-striated mass, surrounded by small spindle-shaped elements, holding a star-shaped protoplasmic body in its center; *C*, cementum; *M*, multinuclear body, so-called myeloplax, from which a globular body may originate; *IE*, inflammatory elements, crowded in the pericementum. Magnified 200 diameters.

Lastly, true bony new formations may occur on the wall of the alveolus, which, after repeated attacks of pericementitis, as clinical observation teaches, is sometimes supplied with thorny new formations of bone. These exostoses originate on the socket of the tooth from the medullary tissue, in the same manner in which exostoses grow on any other bone as sequelæ of periostitis and osteitis. In the highest degree of development these exostoses of the socket replace the pericementum to such an extent that only traces of the pericementum are left. No instance, however, at least to my knowledge, has been observed of a complete fusion of the socket with the tooth.

Purulent Pericementitis.—This form of inflammation is invariably the outcome of an acute process with supervening infection with staphylococci, at least according to the most modern bacteriological views. The invasion is explicable, if the micro-organisms have access to the inflamed pericementum through a carious cavity or a broken root of a tooth.

Numerous cases are, however, on record in which teeth with living pulps have become affected by suppurative pericementitis. In such cases we surmise that the staphylococci were carried into the pericementum by some foreign body accidentally pushed into the socket below the gums and the neck of the tooth.

The possibility cannot be denied that staphylococci may circulate temporarily in the blood and then settle down in the inflamed pericementum, causing suppuration.

The disease is either acute or chronic, and may appear in either of these forms at the neck of the tooth as marginal, or in a limited portion of the pericementum as circumscribed, or at the apex of the root as apical pericementitis or as alveolar abscess. The first-named form is usually termed pyorrhœa alveolaris. Either of the forms named, though originally limited to a portion of the pericementum, may become diffuse, affecting most of the tissue, and may run an acute or a chronic course.

Marginal Purulent Pericementitis is usually termed *pyorrhœa alveolaris.* In this, as in any other suppurative process, a certain amount of the tissue involved is destroyed.

Under the microscope, the first stages of suppurative pericementitis are identical with those of the plastic form,—viz, there are nests of inflammatory elements between bundles of unchanged connective tissue. (See Fig. 232.) The less, therefore, of this connective tissue is left, the more numerous the inflammatory elements are, the nearer is the tissue to suppuration.

With high magnifying powers of the microscope we see that the inflammatory process goes on in exactly the same way as in plastic pericementitis. The bundles of connective tissue are transformed directly into inflammatory elements, which at first are all united with one another. This union of the inflammatory elements is recognizable in relatively large nests also, in which there are but scanty capillary blood-vessels left. It is only after the mutual connection of these elements is broken that the bodies, now isolated, deserve the name of pus-corpuscles, which are suspended in an albuminous fluid, and fill a cavity termed an "abscess." This, if finding exit to the surface around the neck of the tooth, exhibits the typical pyorrhœa alveolaris. After the elimination of the pus, the surrounding inflamed tissue grows in the form of so-called "proud flesh" or granulations, which we not infrequently meet at the neck as well as on the roots of teeth extracted during an attack of suppurative pericementitis, being especially well developed in the bifurcations between the roots of molars. Such granulations are built up by a myxomatous connective tissue, which is freely vascularized, and after having filled the cavity of the abscess, is transformed into dense fibrous connective tissue. Such reparative tissue is termed a "cicatrix." Suppurative pericementitis will invariably heal by cicatrization.

The morbid anatomy of pyorrhœa alveolaris has been studied by Wm. H. Atkinson* on the teeth of a cat, his conclusions being shown in the following abstract:

"Whether suppuration must be present before deposition of lime-salts can only be settled by a study of proper microscopical specimens in the very earliest stage of the disease. The deposit was formerly called tartar, but is now known to be a deposit of lime-salts, phosphate of lime, with some carbonate of lime, entangled with leptothrix, a growth which is rather common around the teeth of almost every person. If a specimen be placed in a solution of chromic acid, the lime-salts will be dissolved, not only of the hard tissues of the tooth, such as dentine, enamel, and cementum, but also from the deposit erroneously called tartar; and ultimately, under the microscope, nothing will be seen but a heap of leptothrix, more or less firmly attached to the neck of the tooth.

"In one specimen, the epithelial covering of the gums has taken a bright pink, the connective tissue a pale pink, the dentine remaining a bright green from the reduction of the chromic acid, and the bone of the socket a dark green for the same reason. Blood-vessels filled with blood retained their original color, not being affected by the carmin. I have to add that neither the horny layer of the epithelium nor the growth of leptothrix has been influenced by the carmin, as they retained a slight brownish-green color. All micro-organisms are known to resist the dye of carmin; whereas they eagerly take up all sorts of anilin dyes. Thus a single specimen shows a variety of colors, which serves as assistance for the discrimination of otherwise not well-marked tissues.

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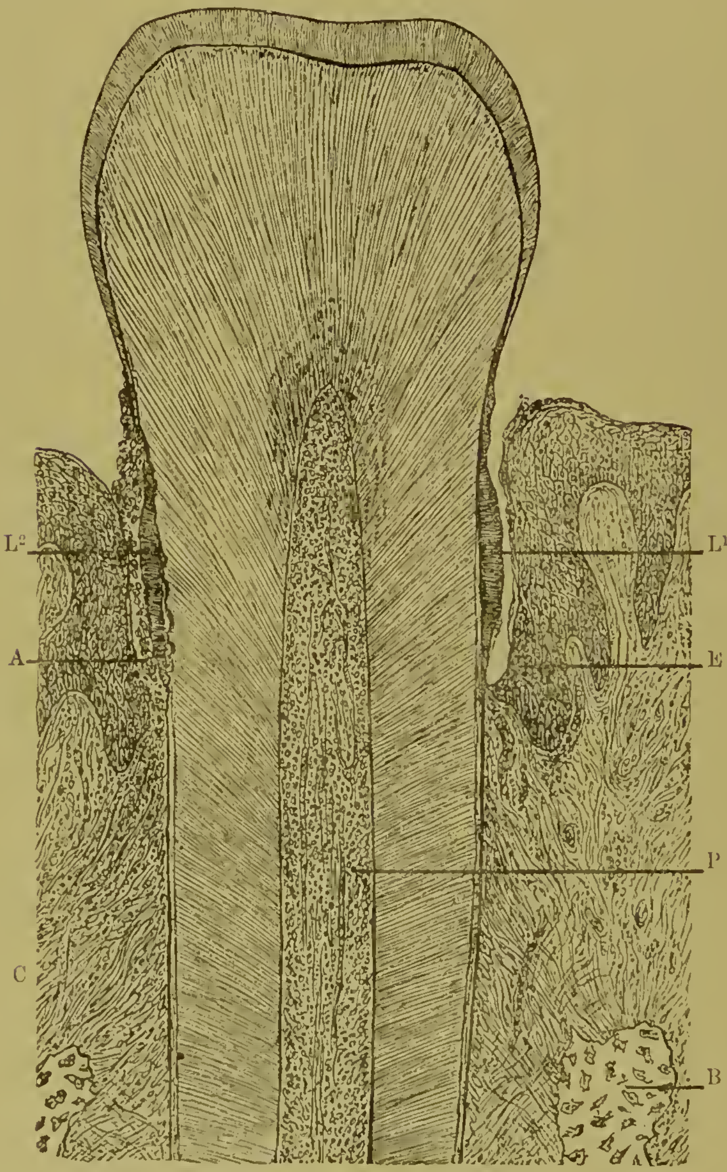
* *Dental Cosmos*, 1888.

Fig. 239.

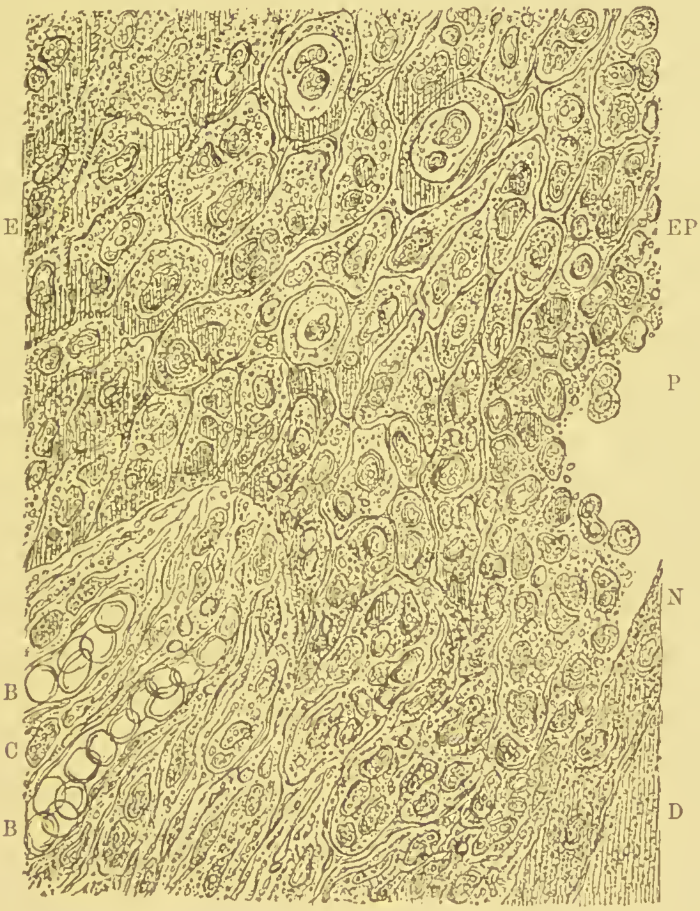


Temporary Molar of a Kitten Six Weeks Old, showing the Earliest Stages of Pyorrhœa Alveolaris.

P, pulp-tissue with capillary blood-vessels; *B*, bony socket; *C*, fibrous connective tissue, producing upward the stroma and the papillæ of the gum, downward the pericementum and the periosteum; *E*, epithelium; L^1, cluster of leptothrix deprived of its lime-salts; L^2, cluster of leptothrix upon an eroded neck of tooth and entangled with pus-corpuscles; *A*, cavity filled with pus in continuity with the pericementum. Magnified 50 diameters.

"For low powers of the microscope, just sufficient for obtaining topographical views, a molar was selected, in which the features I am about to explain are beautifully marked. (See Fig. 239.) The specimen is taken for illustration because on one side of the neck of the tooth the recession of the gum and the growth of leptothrix is marked, without apparent suppuration; while on the other side the growth of leptothrix has led to marked structural changes in the cementum of the neck, in the epithelium of the gum, and in that portion of the pericementum in contact with the uppermost portion of the neck, which by anatomists has been called ligamentum dentium.

FIG. 240.



FORMATION OF PUS FROM CONNECTIVE TISSUE AND EPITHELIUM IN PYORRHŒA ALVEOLARIS OF A KITTEN SIX WEEKS OLD.

E, epithelium of gum with proliferating nuclei; *EP*, epithelium in transformation to pus-corpuscles; *P*, pus-corpuscles sprung both from epithelium and connective tissue; *C*, connective tissue of gum; *B*, *B*, blood-vessels filled with corpuscles; *N*, cementum of neck of tooth; *D*, dentine. Magnified 600 diameters.

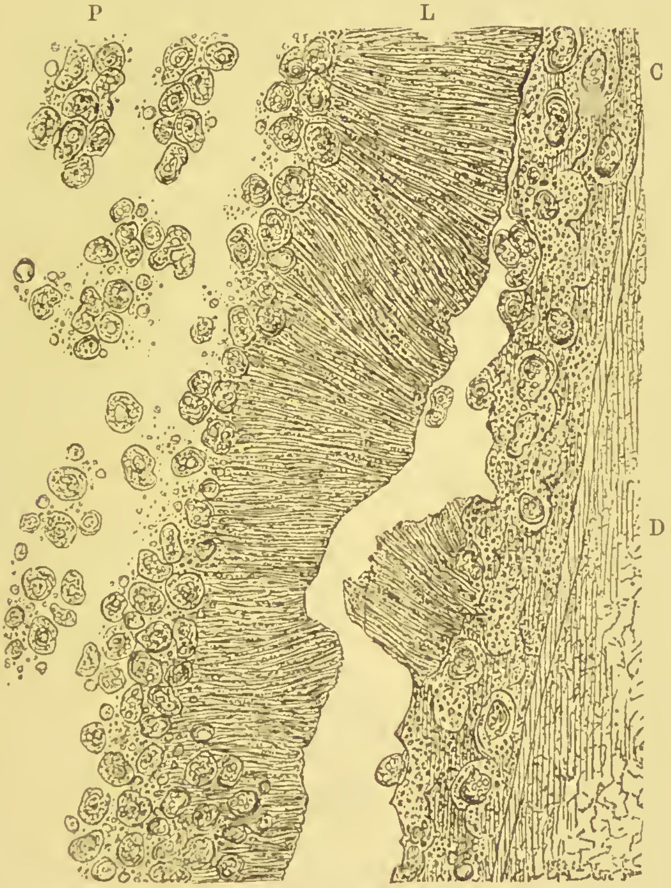
"No sign of trouble below the pouch, or pocket, is seen on the right side of the specimen, except a slight hyperæmia, marked by slightly-dilated blood-vessels filled with blood-corpuscles. We see in the connective tissue, furnishing the papillæ as well as the pericementum, a gradual transition from basis-substance to pus-corpuscles. At first the connective tissue appears granular; later granular or solid lumps make their appearance; and at last the basis-substance has almost completely disappeared, being replaced by a number of so-called inflammatory corpuscles. As soon as the latter become isolated they represent pus-corpuscles, which invariably are intertwined in smaller lumps and scattered granules, probably from a disintegration of some pus-corpuscles. (Fig. 240.) Here we observe a gradual increase of the living matter of the epithelia from a mere division or splitting of the nuclei to a considerable increase of lumps within the epithelia, and to their breaking up into isolated lumps or corpuscles,—viz, pus-corpuscles.

"In epithelial layers the cement-substance between epithelial bodies holds a good deal of living matter in the shape of connecting filaments, previously termed the thorns. Close observation shows that these thorns at first increase in bulk; afterward coalesce into solid cord-like formations; farther on swell up to pear- or club-shaped formations, which themselves split up into pus-corpuscles, thus adding to those visible in an abscess. The pus-corpuscles sprung from previous epithelia are in no way different from those originated from previous connective tissue.

"To-day it is an established fact that suppuration will not take place either in connective tissue or in epithelium, without the presence of certain micro-organisms which are known as staphylococcus, or Streptococcus pyogenes aureus, albus, or citreus. It is a great question yet to decide whether it is micro-organisms themselves penetrating the protoplasm, thus inducing disintegration of the tissue, or whether it is the chemical product of the micro-organisms, the ptomaines, that induce the suppuration. However this may be, the specimens here presented furnish conclusive proofs that, so long as the horny or pavement epithelium is present as a protective layer, no invasion of micrococci will occur. As soon, however, as this protective coat is lost, the micro-organisms may penetrate both epithelium and connective tissue, at once inducing mischief.

"On the right side of Fig. 239 the pouch between the tooth and the gums is lined all around by flat epithelia; there is a marked hyperæmia of the connective tissue, but no marked inflammation or suppuration. On the left side, on the contrary, the pavement epithelium is lost at the bottom and the sides of the pouch, and suppuration has started at once. Whether or not the growth of leptothrix alone is sufficient to excite inflammation or suppuration is not settled, but we can easily conceive of a possibility that together with the leptothrix other micro-organisms are carried along, being ready for the invasion of the formed tissues as soon as the protective horny layer is lost.

Fig. 241.



CEMENTITIS INDUCED BY A GROWTH OF LEPTOTHRIX ON THE NECK OF THE TOOTH OF A KITTEN SIX WEEKS OLD.

L, leptothrix; *C*, cementum of neck; *D*, dentine of the neck destitute of canaliculi; *P*, pus partly entangled with leptothrix. Magnified 600 diameters.

"Attention has been given to the morbid changes of the cementum at the neck, wherever they come in contact with the leptothrix. (See Fig. 241.)

"Some observers claim that even a simple inflammatory process may be produced by the presence of micro-organisms. This assertion I am not able to sustain from the study of my specimens, or any that I have seen. True, wherever leptothrix has encroached upon the hard tissues of the tooth, a melting down of the lime-salts of such tissue will be the result. In the milder forms of such a decalcification (so-called) we observe bay-like excavations, partly containing isolated protoplasmic bodies, clearly the offspring of the perfected tissue present even in the hard tissues of the tooth. But the number of such corpuscles is never sufficiently large to warrant the diagnosis of inflammation; all we could claim is a reduction of the hard tissue into soft protoplasm, probably corresponding to a juvenile or embryonic stage of that very tissue. On the left side of Fig. 239 bay-like excavations are discernible, penetrating not only the cementum of the tooth, but also the dentine; still, there is nowhere a symptom of inflammation or caries. Here our microscopical finding again agrees with clinical experience, which teaches us that in pyorrhœa alveolaris the exposed roots of the teeth very rarely become carious, usually exhibiting only a slightly roughened surface."

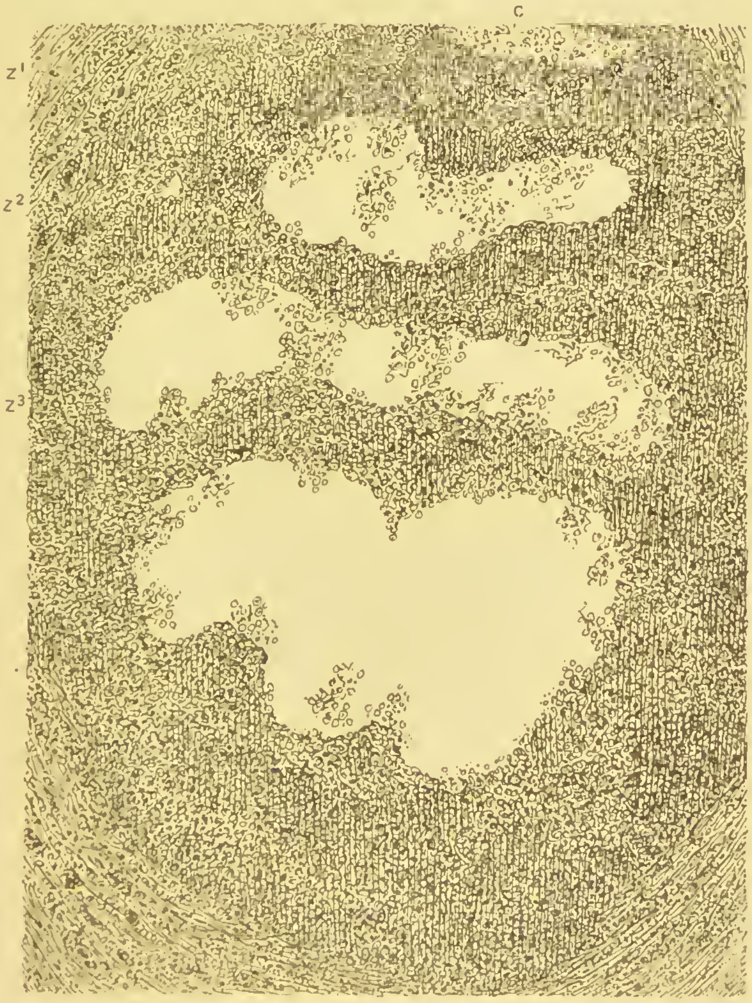
Alveolar Abscess.—This is a peculiar form of suppurative inflammation on the apices of the roots of teeth.

Examinations of microscopical sections through the root, the socket, and the alveolar abscess, demonstrate that the latter is either unilocular or multilocular,—viz, separated into two or several chambers, all filled with pus.

In acute alveolar abscess both the main wall and those of the compartments are crowded with inflammatory corpuscles to such an extent that with low powers of the microscope no vestige of the original fibrous connective tissue of the pericementum is recognizable. At the periphery of the inflamed zone we see a moderately-inflamed layer of pericementum, holding a variable number of brown clusters, obviously remnants of extravasated blood, verging on the formation of pigment. The central portion of a unilocular alveolar abscess is found empty the same as the compartments of a multilocular abscess, because the pus, not being a tissue, is dragged away in the process of section-cutting, both from the inflammatory nests of the pericementum and from the contents of the abscess-cavity. Numerous clusters of staphylococci can be seen with higher powers of the microscope. (See Fig. 242.)

If such an abscess has existed for several weeks or months, it becomes chronic, and then the aspect under the microscope is different from that seen in the acute stage. As a rule, the walls of the compartments have perished by being transformed into pus. A chronic abscess, therefore, will usually appear unilocular.

FIG. 242.



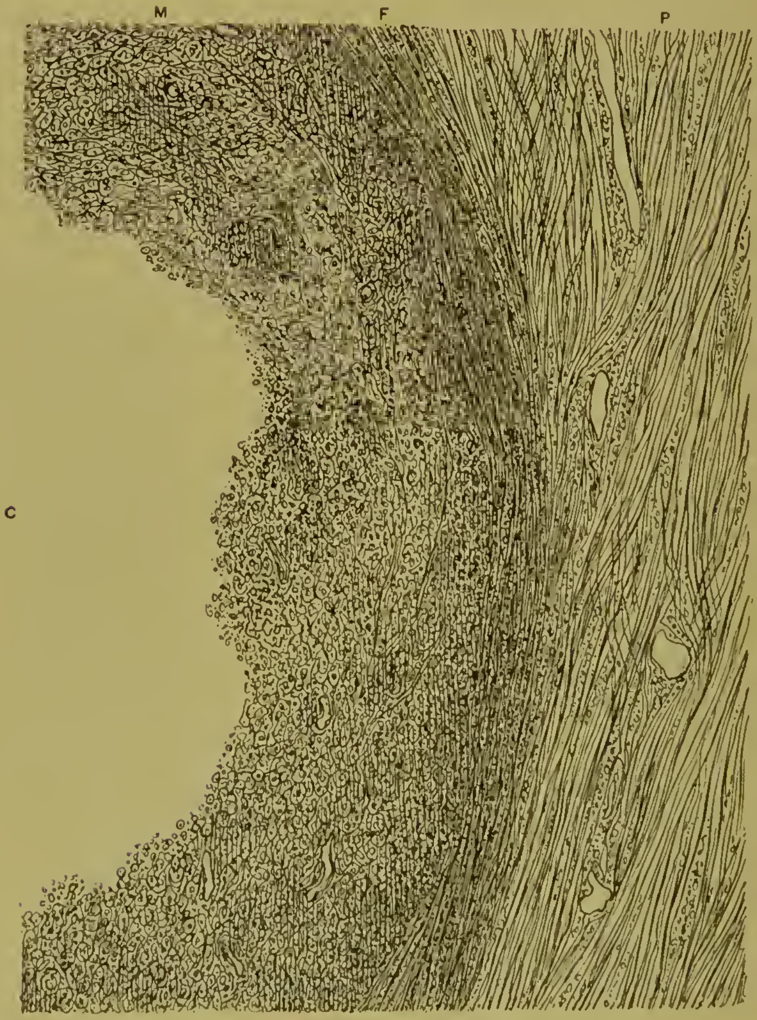
ACUTE ALVEOLAR ABSCESS.—INCIPIENT SUPPURATION IN COMPARTMENTS

C, compartments from which the pus has been removed by the microtome; Z^1, outermost zone, the moderately-inflamed pericementum; Z^2, middle zone, the intensely-inflamed pericementum; Z^3, zone in approaching suppuration. Magnified 100 diameters.

The tissue bordering directly upon the abscess is a broad layer of the myxomatous type, intermixed with delicate bundles of fibrous connective tissue. In this layer a scanty number of newly-formed capillaries are met with. (See Fig. 243.)

This layer has been overlooked by previous observers, and even Virchow termed it "crude pus." To-day we know that it is just the myxomatous tissue which at its innermost portions breaks up into pus-corpuscles, thus augmenting the size of the pus-cavity. (See Fig. 244.)

Fig. 243.



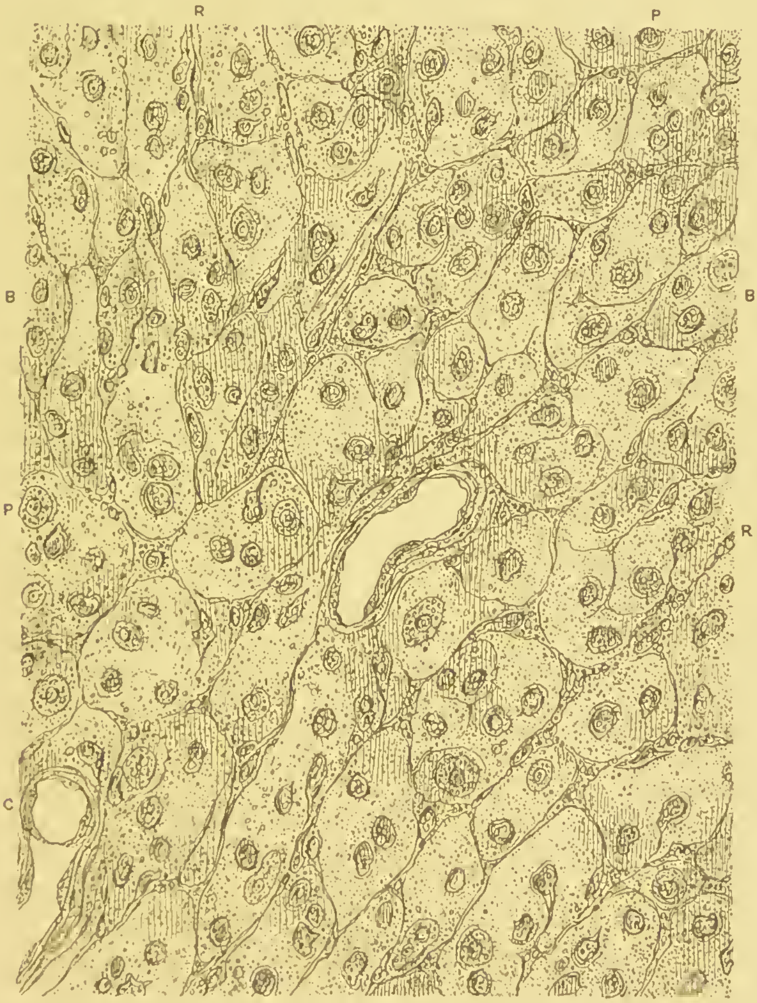
Wall of Chronic Alveolar Abscess.

M, myxomatous portion of wall; *F*, fibrous portion of wall (so-called membrana pyogena); *P*, periosteum slightly inflamed; *C*, pus-cavity, pus-corpuscles removed by section-cutting. Magnified 100 diameters.

We know also that after the evacuation of the pus it is the myxomatous layer which, by a luxuriant growth, furnishes the richly-vascularized granulation-tissue.

At the periphery of the myxomatous wall of the abscess we notice a dense layer of newly-formed fibrous connective tissue, the wall proper of the abscess, which by old surgeons was termed "membrana pyogena." That this layer is newly formed, appears clearly from the fact that its bundles run a concentric course around the abscess, noticeably different from those of the original pericementum. (See Fig. 243.)

Fig. 244.



Innermost Portion of Wall of Abscess. Myxomatous Tissue.

R, *R*, partly protoplasmic, partly fibrous reticulum; *B*, *B*, myxomatous basis-substance; *P*, *P*, protoplasmic bodies in various stages of development; *C*, capillary blood-vessel. Magnified 500 diameters.

As a matter of course, an intense purulent pericementitis will easily affect the periosteum. It is not infrequent that, owing to complete destruction of the blood-vessels of the periosteum and the medulla, serving for the nutrition of the bone, this latter becomes necrotic. (See chapter on Necrosis.)

When the inflammatory process has lasted for months, the newly-formed connective tissue assumes a distinct fibrous structure, and between the bundles there are interspersed nests of inflammatory elements. These may be partly transformed into fat-granules, or produce opaque layers in fatty degeneration. If, on the contrary, the alveolar abscess be of a more recent date, the fibrous structure of the sac is plainly marked on its periphery only, while the central portions bear the character of a myxomatous granulation-tissue. The strings or the septa, traversing the abscess, may eventually, in accordance with the duration of the disease, be found either of a fibrous or myxomatous structure. In both instances we often meet with a large number of newly-formed capillary blood-vessels. The inner surface of the sac is not smooth, but largely provided with irregular protrusions, or papillary outgrowths of a myxomatous structure, crowded with inflammatory elements. The sac contains inspissated pus, which, upon the cutting of microscopical sections, crumbles away.

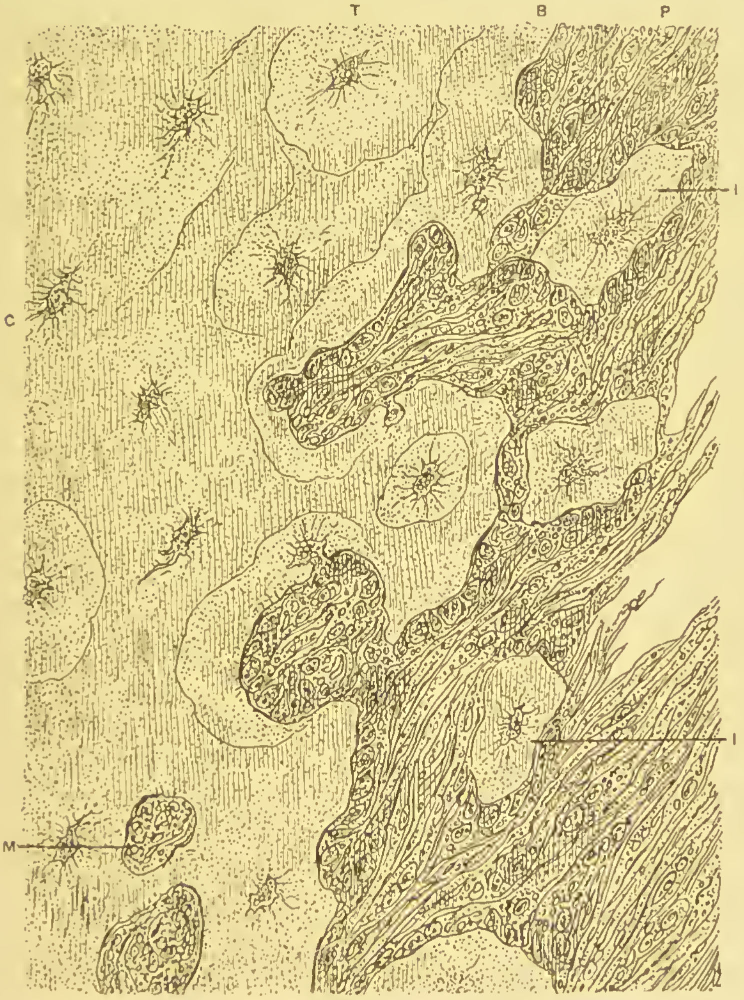
Cementitis and osteitis always accompany an alveolar abscess. Cementitis leads to a destruction of the cementum in the shape of deep, irregular, bay-like excavations, which exhibit all stages, from the liquefaction of the basis-substance up to the transformation of the living matter into pus-corpuscles. Sometimes the excavations penetrate the dentine. In the highest degrees of pericementitis the apex of the root, inclosed in the alveolar abscess, is transformed into a thin, jagged, and corroded stump, with but scanty remnants of the former cementum.

Osteitis (inflammation of the wall of the alveolus) is an inevitable result of the formation of an alveolar abscess. The portion of the socket in contact with the sac of the abscess is widened, its surface being either smooth or jagged. Examination with the microscope leaves no doubt that the inflammatory elements, sprung from the bony tissue after dissolution of its lime-salts and liquefaction of its gluey basis-substance, become spindle-shaped, and share largely in the formation of the wall of the abscess.

In higher degrees of osteitis the wall of the alveolus is reduced to irregular, eroded trabeculæ of bone, the outer surface of which is lined by a dense, newly-formed connective tissue, identical with that of the wall of the abscess. The neighboring medullary spaces are enlarged and crowded with inflammatory elements.

Considerable interest attaches to the healing process of pericementitis and cementitis, such as we are able to observe in chronic alveolar abscess, after the subsidence of the inflammatory symptoms. (See Fig. 245.) We observe a transformation of the inflamed pericementum into irregular tracts of fibrous

Fig. 245.



Healing Process of Pericementitis and Cementitis.

P, pericementum consisting of newly-formed fibrous connective tissue; *B*, border of cementum with bay-like excavations; *T*, zone of cementum with faintly-marked territories; *C*, unchanged cementum; *I*, *I*, islands of territories of cementum; *M*, medullary space. Magnified 100 diameters.

connective tissue, still plentifully supplied with globular and spindle-shaped protoplasmic bodies. In this tissue we find inclosed irregularly recalcified territories of cementum, with faintly-marked central cement-corpuscles. The border-zone of the cement is conspicuous by its deep, bay-like excavations, filled with newly-formed pericementum. At some distance from the border, the outlines of the recalcified territories of the cement-corpuscles are still recognizable. In this zone we notice apparently isolated medullary spaces, which probably are in continuity with the surface of the cementum and have escaped recalcification. After the accomplishment of the latter process, the cement-corpuscles have resumed their original shape, though many of them appear a trifle larger and more irregular than the original cement-corpuscles.

CHAPTER XL.

CARIES OF THE TEETH.

The modern views in regard to the origin of caries of the teeth are based upon bacteriological researches. Previous to 1882, before bacteriology became a systematized science, the origin of caries was thought to be a mere decalcification of enamel and dentine, accompanied by a growth of micro-organisms. But even at that time much valuable work was accomplished. The proof that the living tissues of the teeth, if attacked by the process of caries, react by an inflammatory process, was then a great step in advance, a fact which has altogether been neglected by bacteriologists. In order to do justice to both parties, I deem it advisable to give the views held by Frank Abbott* and those announced by W. D. Miller, of Berlin.† The former was published in ante-bacteriological times, the latter is founded entirely on bacteriological research. I am convinced that only by a combination of both the inflammatory and the bacteriological doctrines the full truth will be reached.

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* *Dental Cosmos*, 1879.

† "The Micro-Organisms of the Human Mouth," 1890.

Frank Abbott's Views.*—" *Etiology.*—The first lesion under all circumstances is due to the action of an acid, which in a merely chemical way dissolves out the lime-salts from the enamel. No doubt quite a strong acid is necessary for decalcification of so solid a tissue as the enamel of a tooth. And the question next arises, Where does this acid come from ?

" First let us take into consideration the starting-points of the morbid process. I fear no contradiction on the part of my professional brethren when I say caries never begins on the smooth surfaces of a tooth, which are exposed to the friction of mastication, but always starts on points which, owing to their anatomical structure, form receptacles for food, etc., or on points between the teeth where, owing to want of cleanliness, decaying material can accumulate. It is therefore not to the friction between the single teeth (Salter), which, as we know, is possible to a certain extent in the normal condition, but to the acid generated from the decaying material retained between the two flat or concave surfaces which the teeth present to each other, that the beginning of the destruction of enamel is due.

" That this decaying material may be sought for and found in the food, I think will hardly admit of a doubt; and, as it occurs to me, mainly in such kinds of food as through their decomposition are apt to produce an acid, not very strong, perhaps, in itself, but possessing a high degree of affinity for lime-salts,—viz, lactic acid.

" First among the varieties of food ranks meat, which by putrefaction may produce free lactic acid; next are the saccharine materials; and last the amylaceous, which being converted into dextrine by the action of the saliva, may be transformed, if brought in contact with putrefying meat, into lactic acid. There is no doubt that the organic portion of teeth, as it advances to the stage of decomposition in the process of caries, plays a very important part in the formation of this acid.

" Perhaps the sour decomposition is assisted locally by the action of micrococci and leptothrix; although these organisms are known to prosper only in alkaline, and not in acid fluids. These vegetable organisms are present in innumerable quantities on the healthiest gum; tartar is crowded with them. And even in the highest degrees of development of tartar *caries* is *absent*. In fact, when decayed cavities in the teeth become filled with tartar, the carious process is as effectually stopped as it is possible for it to be when such cavities are *filled* in the most perfect manner with gold or any other favorite material. Hence I do not consider the views of those authors correct who claim that micrococci and leptothrix play any important part in producing, or even supporting, the carious process.

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* This was first published in 1879. Professor Abbott has been kind enough to furnish me, especially for this book, with his present views, as expressed in the conclusions of his original paper The headings I, II, and III of the results of his studies are changed by himself.

"I fully concur, however, with the views of those who claim that the resistance of the teeth against caries, owing to their amount of lime-salts, greatly varies in different people. The hue of the teeth, as is well known, is indicative to some extent of their amount of lime-salts. The microscope shows a considerable variety, with regard to the presence or the degree of density, of that layer of the basis-substance surrounding the dentinal canaliculi. E. Neumann first drew attention to this layer, which sometimes is so dense and so well defined, owing to its greater refracting power than that of the basis-substance between the canaliculi, that it may be regarded almost as a protecting sheath to the living matter within the canaliculi. This layer is well marked even in fossil teeth; it resists somewhat the action of strong acids and alkalies, but it is almost completely absent in a number of carious teeth which I have examined. I have also remarked that different teeth, treated exactly in the same manner with chromic-acid solution, become soft in a markedly shorter space of time than others. The general health or constitution may have considerable influence upon the quantity of lime-salts deposited in the basis-substance of the teeth.

"Nations of high civilization, which inevitably leads to bodily and mental depravation, as a rule have a greater percentage of carious teeth than those of a low degree of culture, or with no culture at all.

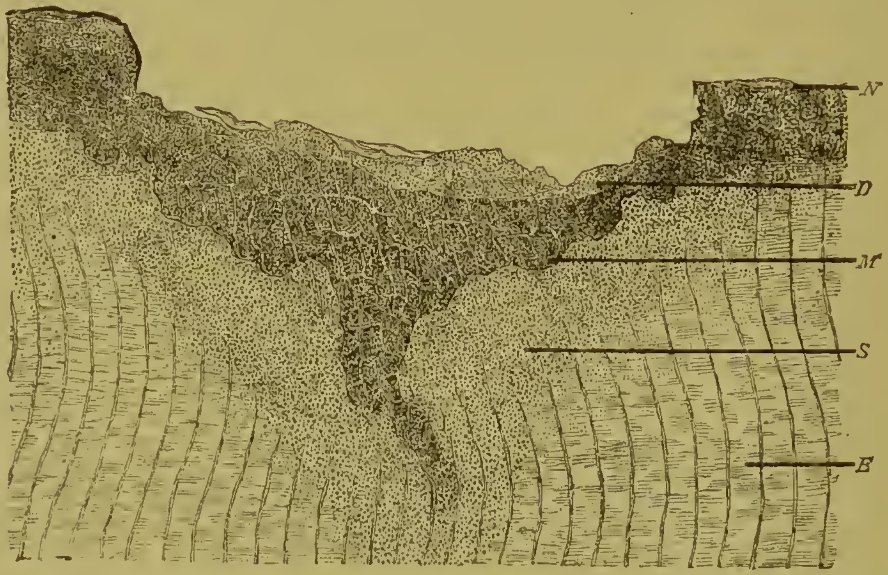
"However this may be, the fact that caries of the teeth begins as a chemical process scarcely will, in my opinion, be questioned. On a dead tooth, natural or artificial, as well as on teeth manufactured from the dentine of the elephant or the hippopotamus, the process will remain, under all circumstances, a chemical one, assisted only by the putrefying remains of the organic material of the tooth; while on a live tooth either acute or chronic reaction-changes take place, which I intend presently to consider.

"*Caries of Enamel.*—The clinical phenomenon of caries, in its very origin, consists essentially in a discoloration of the enamel. A whitish or grayish spot on the surface of the enamel is indicative to an experienced eye of the beginning of decay, which spot proves, when touched with an instrument, to be soft and crumbly. Often a brown spot is visible on the enamel as a sign of the softening process. The less pigmentation present, the more rapid is the process of decay. On the contrary, the more distinct the discoloration, the slower is the softening process. Nay, dark-brown spots may be present in the enamel for many years without being followed by softening. The brown discoloration, as such, cannot be considered as an essential feature of caries of enamel, but it usually accompanies the carious process, and does so the surer the slower the morbid process runs. On microscopic specimens we meet with decayed pits in enamel without any discoloration of this tissue. On other specimens we have a very marked orange or brown hue on the decayed part as well as in its neighborhood, and sometimes scattered specks are to be seen some considerable distance from the diseased part. The brown discoloration is located in the basis-substance of the enamel-rods, the outlines of which are much more marked than when in a healthy condition. The interstices between the rods here are plainly visible even with a magnifying power of only 500 diameters. This power will reveal delicate beaded fibers of living matter within the interstices, which in healthy enamel can be seen distinctly with a power of 800 to 1000 only. Besides the discoloration, no material changes are seen in the enamel-rods.

" What process the pigmentation of the enamel is due to I cannot say, but it occurs to me that we have no right to look upon this process as a merely chemical reaction upon the basis-substance of the rods. That in fact it is the basis-substance holding the pigment, and not the lime-salts deposited therein, is proven by specimens from which the lime-salts have been extracted to a considerable extent by chromic acid, and which still show the brown stain. I dare say that this brown discoloration is a strong proof of the presence of life in the enamel, as in teeth where the pulps are dead such stains never appear, nor can they be produced by artificial means. The process of decay in the enamel can best be studied on superficial erosions of the same, a sample of which I have illustrated. In this instance the brown discoloration of the decayed part was but trifling, and entirely absent in its vicinity, so that we have to consider it as a case of acute caries.

"We see at *E*, Fig. 246, the unchanged enamel partly deprived of its lime-salts. Toward the periphery a zone appears in which the enamel-rods are spotted, evidently owing to their partial decalcification. Close to this and immediately below the decayed part a zone is visible in which the enamel is granular, and looks precisely like normal enamel from which, by a somewhat stronger solution of chromic acid, the lime-salts have been dissolved out. Here the protoplasmic condition of the enamel is re-established simply by disorganization, and there is no doubt that this is the very condition of the enamel by which the white spot is produced upon the surface while the tooth is still in the jaw. On the boundary of the enamel we see a shallow depression filled with protoplasmic bodies, which represent either complete enamel-prisms or lumps of such prisms. All these protoplasmic formations are united with one another by delicate threads; they exhibit but a slight

FIG. 246.



ACUTE CARIES OF ENAMEL.

E, unchanged enamel; *S*, enamel deprived of its lime-salts; *M*, enamel broken down to medullary corpuscles; *D*, medullary corpuscles indistinctly marked; *N*, flat epithelia. Magnified 1000 diameters.

brown discoloration, they readily imbibe carmin, and if the specimen be stained with a half per cent. solution of chloride of gold these bodies assume a dark-blue tinge, while the unchanged enamel is but little affected by this reagent. On the outermost layer we see several flat epithelial bodies attached to the protoplasm, which in the transverse section look irregularly spindle-shaped, and are evidently the remnants of the so-called Nasmyth's membrane, or enamel-cuticle, sunken down with the decaying protoplasm. On the level of the enamel we also recognize such flat epithelia. Beneath them on the right side of the drawing there is present a zone of decalcified enamel, while on the left side the division into protoplasmic bodies is fully accomplished.

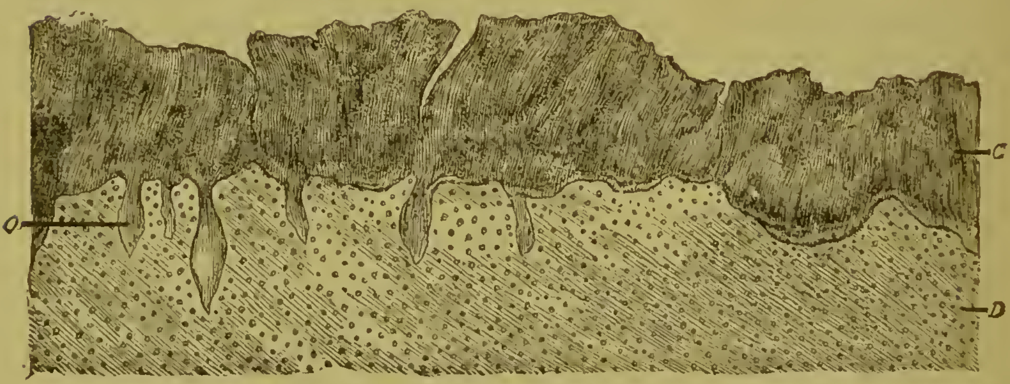
" Not a trace of micrococci or of leptothrix is visible in or above the decayed pit of the enamel, which again proves that these organisms do not play any important part in the process of caries; at least, do not materially interfere with the tooth in its normal condition.

" The way in which the caries proceeds downward is plainly shown by the figure. There are small, irregular, bay-like excavations on its boundary, and in the midst of the decayed part a wedge-shaped elongation is running downward into the softened enamel. The shape in which caries appears in the enamel is, however, greatly varying. Besides the wedge shape as illustrated in the figure, the forms in which caries proceeds are shallow or conical excavations, with abrupt walls, fissures, and grooves. On the bottom of the main excavation we sometimes see a smaller cavity, it being in a narrow or wide communication with the main decayed mass.

" Besides the peculiar medullary elements forming the contents of a carious cavity of the enamel in its initial stage, I not very rarely have met with dark-brown, irregularly-shaped clusters filling the whole cavity. How such changes of medullary corpuscles are produced I am unable to say, although it seems to be kindred to the so-called *colloid* or *hyaloid* metamorphosis which we observe in other tissues, the only difference being that in caries the colloid clusters are deeply saturated with a uniform brown pigment, the origin of which, as mentioned above, is unknown.

" *Caries of Dentine.*—Upon examining a large number of teeth with carious dentine, we are struck by conditions to the presence of which no observer has as yet drawn attention. Sometimes the dentine, attacked by caries, looks but little changed on its periphery. A narrow zone of yellowish color forms the boundary toward irregular, shallow excavations (see Fig. 247). At other times, besides the bay-like excavations on the periphery, there are visible elongations, cylindrical, conical, pear-shaped, or leaf-like, passing down into the dentine in varying depths (see Fig. 247, *O*). There is no doubt that this form of decay of the dentine occurs with the least preliminary changes of the tissues; it evidently runs a slow course, and I think I am justified in calling this form of caries chronic. It seems evident that decay of a tooth assumes an acute or chronic form just in proportion to its perfect or imperfect calcification.

Fig. 247.



Chronic Caries of Dentine.

D, dentine; *O*, the process of decay penetrating into dentine in the shape of short offshoots; *C*, decayed mass. Magnified 200 diameters.

Dead teeth in which the pulps have been destroyed either by necrosis as a natural process, or by artificial means with caustics, very frequently run this kind of slow or chronic decay. The decay of artificial teeth, either human or ivory, in all probability runs either an acute or a chronic course, according to the amount of lime-salts infiltrated into the glue-yielding basis-substance.

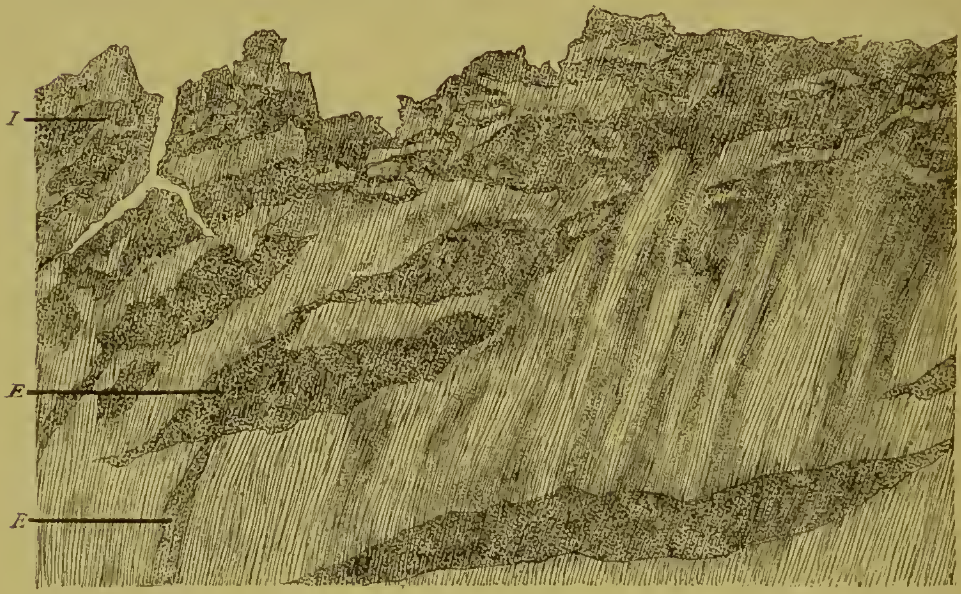
“ I have examined a piece of a hippopotamus tooth which, for a period of about one year, was worn in the mouth of a patient, and a spot became decayed about the size of a hemp-seed. I softened this piece with chromic-acid solution, imbedded it in paraffin and wax, and cut thin sections with a razor. On the bottom of the decayed pit numerous conical spots appeared running downward into the dentine, characterized by the absence of coloring-matter in specimens stained with carmin. No material change besides was observable; even the dentinal canaliculi did not look enlarged. The bottom of the carious cavity was covered with a layer of finely-granular, evidently disintegrated organic material, and above this the ordinary masses filling carious cavities in teeth,—viz, micrococci and leptothrix,—were visible.

"In chronic caries merely a chemical process takes place, assisted by putrefaction of the organic constituents of the tooth. Here first the solution of the lime-salts of the dentine takes place, either along the bay-like excavations or in the shape of longitudinal depressions. No reaction whatever follows this process. The glue-yielding basis-substance being deprived of its lime-salts shows a yellow discoloration, and only traces of the dentinal canaliculi. The basis-substance then breaks down into an indistinct granular mass, which is immediately filled with a new growth of low vegetable organisms,—viz, micrococci and leptothrix.

"My specimens plainly show that these organisms are not the *advance guard* in the process of decay. The first change that takes place is exposure of the basis-substance by the chemical action of some acid, independent of the named organisms, which come to view only after complete disintegration of the basis-substance. I never have seen the penetration of these organisms into the dentinal canaliculi before a thorough decalcification of the basis-substance had taken place. No doubt, however, the decayed mass itself may be crowded with such organisms which they seem to form with. In the great majority of my specimens I have met with formations on the diseased boundary of the dentine which demonstrate a considerable degree of reaction, produced by the irritating power of the same agent, to which the lime-salts of the dentine yield. In fact, this was the case in all teeth which were alive when attacked by the carious process, or rather when removed from the jaws. On the boundary of this process we see irregularly-shaped elongations running a certain depth into the tissue of the dentine. The more superficial the elongations are, the surer the morbid process may be termed a slow one; and, on the contrary, the deeper the elongations, the more certain we may be that the morbid process has advanced rapidly. The elongations mainly have the shape of fissures filled with a dark granular material, if viewed with a low power. These fissures run independently of the direction of the dentinal canaliculi; nay, very often cross them. (See Fig. 248.) In the specimens they look, as a rule, as if communicating with each other, and also directly or indirectly with the decayed outer surface. Sometimes the fissures appear completely isolated, though we may assume that they are separated from the communication with analogous and more superficial formations only by the method of preparation,—viz, cutting into thin lamellæ.

"On the surface of the carious portion of dentine we see irregular cavities filled with the same granular mass that is present in the fissures, consisting evidently of débris of the former tissue, together, perhaps, with micrococci, and very often fine thread-like leptothrix. The more rapidly the destruction of the dentine has advanced, the more irregular islands of dentine are left on the surface.

Fig. 248.



Acute Caries of Dentine.

E, *E*, fissures in which the decay penetrates into the dentine; *I*, small islands of unchanged dentine. Magnified 200 diameters.

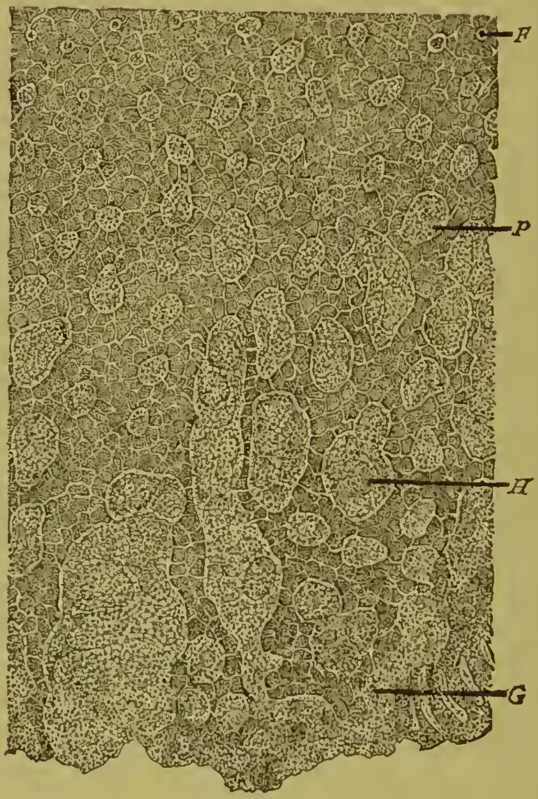
"In our figure the decay evidently has proceeded rapidly; hence the remnants of the former dentine, recognizable by the presence of the canaliculi, are very small and irregular on the outer periphery of the dentine.

"The outermost portion of the decayed part is, as a rule, brittle, and crumbles away in chromic-acid specimens. Where it is left it shows a crowd of leptothrix and micrococci, without any distinctly recognizable remnants of the former tissue. On the boundary of the carious portion we, as mentioned above, meet with a yellow discoloration of the dentine, evidently produced by an inflammatory reaction, which first breaks down the organized constituents of the lime-salts and in turn liquefies the glue-yielding basis-substance. In live teeth the yellow discoloration usually takes place in the shape of longitudinal strings of different diameters, running mainly parallel with the longitudinal direction of the dentinal canaliculi. Nay, we often see single yellow strings running from the bottom of a carious cavity in the enamel through the whole depth of the dentine to the pulp-chambers. (See Fig. 248, *E*, *E*.) The best method for demonstrating these strings is doubtless the staining of chromic-acid specimens in an ammoniacal solution of carmin. While the unchanged dentine readily takes up the carmin, the strings, the deep yellow color of which is undoubtedly due to the action of the chromic acid, remain unstained.

"With a power of about five hundred diameters, we recognize under the microscope, in longitudinal section of the dentine, that sometimes the yellow discoloration has taken place only within the limits of a few dentinal canaliculi, while at other times quite a number of these have undergone discoloration. Still sharper defined is the yellow discoloration in transverse sections. Here we see that mainly the canaliculi and their immediate neighborhood have taken up the yellow color in the shape of sharply-circumscribed dots, which are the larger the nearer they approach to the periphery of the decayed part. The basis-substance between these yellow spots has taken up more or less carmin. Let us examine such a cross-section with a magnifying power of 1000 diameters under the microscope.

"At a certain distance from the decay the canaliculi look unchanged, and each contains the central transverse section of the dentinal fiber with its delicate radiated offshoots. (See Fig. 249.) Nearer to the decay we meet with moderately-enlarged canaliculi, the center of which is occupied by a cluster of protoplasm, the granules and threads of which have readily taken up the carmin. One step farther we find the canaliculi considerably enlarged, to double or treble their original size, and filled with yellow protoplasm, plainly exhibiting the net-like arrangement of the living matter. The most peripheral granules send delicate conical offshoots through the surrounding light space toward the unchanged basis-substance. In some of the enlarged canaliculi accumulations of living matter are seen fully in the shape of nuclei; sometimes two or more such nuclei may be seen surrounded by a varying amount of protoplasm. Still nearer to the decay the canaliculi are enlarged to ten or fifteen times their original diameter, and the cavities thus produced are all filled with a partly-nucleated protoplasm. Between the roundish cavities we meet with longitudinal cavities, arising from the confluence of several cavities in one main direction. The cavities continue increasing in size, and form large spaces, with rounded, bay-like boundaries, between which only scanty traces of unchanged basis-substance are left. Lastly, the basis-

FIG. 249.

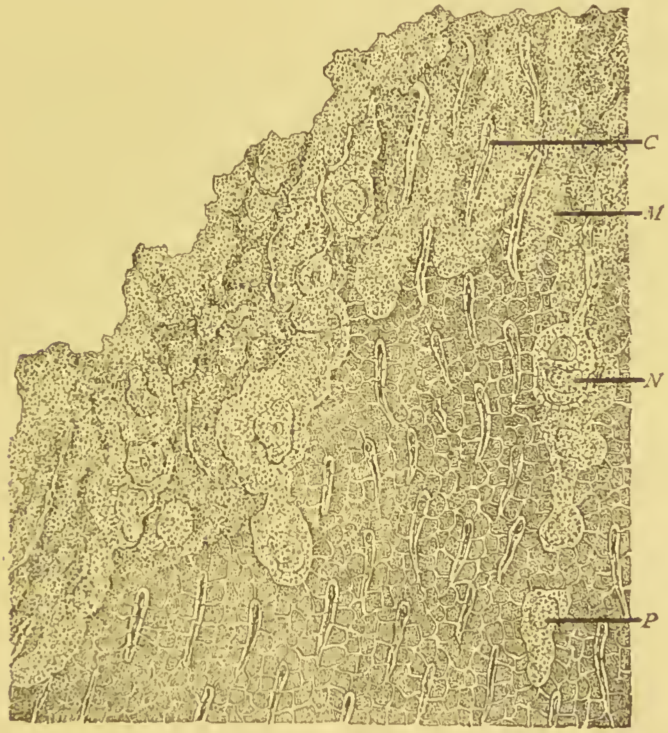


CARIES OF DENTINE.

F, unchanged dentinal fiber; *P*, enlarged dentinal canaliculi, filled with protoplasm; *H*, medullary corpuscles in considerably widened dentinal spaces; *G*, complete transformation of dentine into medullary corpuscles. Magnified 1000 diameters.

substance has entirely disappeared, and only protoplasm is visible in its place, either in the shape of multinuclear layers or of irregular so-called medullary elements with rather faint marks of division. Nearest to the periphery the protoplasm does not exhibit any form elements, but looks like a disintegrated granular mass, probably intermixed with or replaced by micrococci. I say probably, inasmuch as all good histologists agree, nowadays, that the diagnosis of micrococci is possible only when they are clustered together, which is not always demonstrable even in the thoroughly-decayed mass.

FIG. 250.



CARIES OF DENTINE. OBLIQUE SECTION.

P, widened dentinal canaliculi, containing protoplasm; *N*, space containing medullary corpuscles; *M*, transformation of dentine into protoplasm; *C*, trace of dentinal canaliculus containing an enlarged fibril. Magnified 1000 diameters.

"We have a series of changes of the dentine fibers, and the surrounding basis-substance of the dentine before us, which I have not the least doubt is the normal procedure of the transformation of dentine by the carious process.

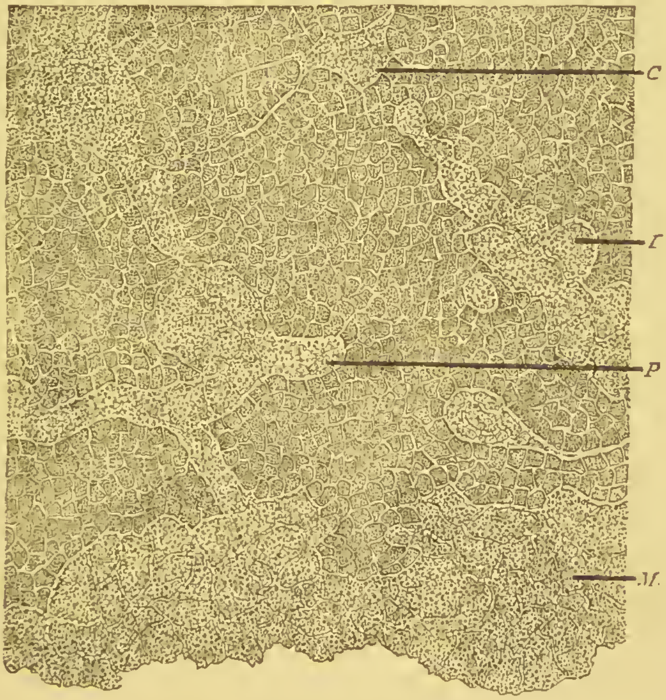
"Fig. 250 is an oblique section, and illustrates exactly the same changes from a tooth attacked by a less acute caries, perhaps owing to its greater solidity or more perfect calcification. Here a relatively small number of dentinal canaliculi are enlarged and filled with protoplasm. The center of the protoplasmic bodies is occupied by one or two nuclei, which look as if they originated from the former dentinal fiber. On the periphery of the dentine there are regular nests filled with protoplasmic formations of the above description, partly broken down into medullary elements. In other parts, on the contrary, the transformation of the basis-substance into protoplasm has even preceded the changes of the dentinal fibers. The canaliculi are not noticeably enlarged; the dentinal fibers are either unchanged or slightly swollen, and more granular than in the normal condition; while outside these we have a thoroughly decalcified and liquefied basis-substance, which means a reappearance of the net-work of the living matter.

" *Caries of Cement.*—So long as the gums are in their normal condition and position, caries does not *begin* in the cement; but if the gums have receded from any cause, thus exposing the cement which covers the necks of the teeth, it may then begin to decay. I never have had an opportunity of examining primary caries of cement under the microscope, but of caries of this tissue advanced from within—viz, from decayed dentine —I have several specimens. The microscope reveals in these specimens a more or less advanced decay, which in its essential features is fully analogous to caries of the dentine when in a live condition; in other words, it is an inflammatory process. On the boundary of the caries we see, besides unchanged cement-corpuscles (see Fig. 251), those which have been enlarged and transformed into medullary or inflammatory elements. Nay, I have observed that the lacunæ holding the protoplasmic body were partly unchanged, while a part participated in the inflammatory process.

" The enlargement of the cement-corpuscles is evidently not due to a direct swelling of the protoplasm itself, but to a liquefaction of the surrounding basis-substance, in which the protoplasmic condition, and with this also the medullary elements which have participated in the formation of the basis-substance, reappear. The inflamed portions of the cement look granular with lower powers of the microscope, but high powers reveal the net-like structure of the living matter, and the formation of irregular polyhedral elements which are separated from one another by a light, narrow seam, this being traversed by extremely delicate uniting threads.

"The history of development of bone demonstrates that this tissue originates from medullary elements, the so-called osteoblasts, which partly remain unchanged, and as such form the bone-corpuscles, while their greater part is transformed into basis-substance (Waldeyer). The history of the development of the cement has not as yet been studied, but we have good reasons for assuming that it develops in a way identical with that of bone, as both tissues are identical in their structure, and exhibit identical results when inflamed.

FIG. 251.



CEMENTITIS DUE TO CARIES.

C, unchanged cement-corpuscles; *I*, space filled with medullary corpuscles; *P*, cement-corpuscles partly unchanged, partly transformed into medullary corpuscles; *M*, the cementum wholly transformed into medullary corpuscles. Magnified 1000 diameters.

"Dr. C. Heitzmann has drawn attention to the fact that the protoplasm of the medullary elements, when transformed into glue-yielding basis-substance, does not altogether perish. It is only the fluid, non-living part of the protoplasm which, by chemical changes, is transformed into glue; the living part of the protoplasm, on the contrary, remains unchanged, and is simply concealed by the refracting power of the *glue-yielding* basis-substance. That this view is a correct one the investigator named has proven by the appearances in inflamed bone, and I can fully corroborate his views from my observations on inflamed cement.

"Virchow's view that the bone-corpuscles swell and divide into inflammatory elements by being converted into proliferating mother-cells, is, in my opinion, wrong. No proliferation is demonstrable in the earliest stages of inflammation of the cement. Nothing but a liquefaction of the glue-yielding basis-substance takes place, in order to bring to view the very same medullary elements which once have shared in the formation of the cement. The inflammatory reaction in the cement-corpuscle itself may be so slight that (as mentioned above) a part of the protoplasm may look almost unchanged, while another part toward the decalcified basis-substance gives an appearance identical with that of the surrounding liquefied basis-substance. The result of this process is a transformation of the tissue of the cement into medullary or inflammatory elements. These remain in connection with one another by delicate threads of living matter, but at last become disintegrated, and furnish, together with micrococci and leptothrix threads, a decayed mass, just as well as enamel and dentine.

"*Results.*—After having examined the teeth attacked by the carious process, microscopically, from the mouths of over thirty different persons, I can sum up the results of my researches in the following aphorisms:

"I. In enamel, caries in its earliest stages is a chemical process. After the lime-salts are dissolved through the inflammatory reaction, and the basis-substance liquefied, the protoplasm reappears and breaks apart into small, irregularly-shaped, so-called medullary or embryonal bodies, and subsequently the lime-salts are dissolved by acids or washed away.

"II. Caries of dentine consists of a dissolution of the lime-salts in the intertubular substance by the inflammatory reaction, a melting down of the glue-yielding basis-substance (matrix) around and between the canaliculi. The living matter contained in the canaliculi proper is transformed into nucleated protoplasmic bodies, which, together with protoplasmic bodies originating from the living matter in the basis-substance, form the so-called indifferent or inflammatory tissue.

"III. Caries of cement exhibits first all phenomena known to be present in the early stages of inflammation of bone. The protoplasmic cement-corpuscles, together with the basis-substance, after its liquefaction, produce indifferent or inflammatory elements.

"IV. The indifferent elements originating through the carious process from enamel, dentine, and cement do not proceed in new formation of living matter, but become disintegrated and transformed into a mass crowded with micrococci and leptothrix.

"V. Caries of a living tooth, therefore, is an inflammatory process, which, beginning as a chemical process, in turn reduces the tissues of the tooth into embryonic or medullary elements, evidently the same as during the development of the tooth have shared in its formation; and its development and intensity are in direct proportion to the amount of living matter which they contain, as compared with other tissues.

"VI. The medullary elements, owing to want of nutrition and to continuous irritation, become necrosed, and the seat of a lively new growth of organisms common to all decomposing organic material.

"VII. Micrococci and leptothrix by no means produce caries; they do not penetrate the cavities in the basis-substance of the tissues of the tooth, but appear only as secondary formations, owing to the decay of the medullary elements.

"VIII. In dead and artificial teeth caries is a chemical process, assisted only by the decomposition of the glue-yielding basis-substance of dentine and cement."

W. D. Miller's Views.*—"PHYSICAL PHENOMENA OF DENTAL DECAY.—*a. Decay of Enamel.*—As the first indication that the process of destruction has begun on the external surface of the enamel, we notice that it has lost its normal polish and transparency; then a white (not black) spot of chalky color appears; a sharp instrument (*e.g.*, the point of a needle) will not easily glide over the surface, but will readily detect the presence of a slight roughness, caused by a softening or disintegration of the enamel, by which it is gradually changed into a soft, cheesy powder. This dissolution of the enamel may be best observed when decay advances from the dentine upon the inner surface of the enamel (secondary decay); here the broken-down enamel-prisms cannot be washed away, so that quite a thick layer of a perfectly white cheesy substance may often be found.

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* "The Micro-Organisms of the Human Mouth." 1890.

"In primary decay the disorganized enamel-prisms are soon mechanically washed away, whereby an excavation or cavity is formed. The form of the cavity depends upon various circumstances,—among others, upon the breadth of surface of contact with the adjacent tooth, also in a high degree upon the structure of the enamel. It is sometimes flat and broad with scarcely distinguishable margins, sometimes narrow and deep with sharp ragged margins. Soon after the commencement of decay, a more or less pronounced discoloration sets in. In my opinion, the view held by some, that the discoloration is to be regarded as the first sign of decay, is based on an error which is to be explained only on supposition that the advocates of this view have not examined decay in its earliest stages. . . . Discoloration appears in very different grades; when the decay proceeds very rapidly (caries acutissima), it is slight or wholly wanting (white decay). In other cases only the margin of the enamel is colored brown to black, while the center of the cavity remains white. When the decay proceeds very slowly,—that is, when it is of long standing (caries chronica),—the greater part of the affected tissue is deep brown or black. This is also the case when the progress of the decay has been interrupted, as is often observed on the approximal surfaces of teeth which have been exposed by extraction of an adjacent tooth. Such cases are usually designated as caries nigra (black decay). This badly-chosen term must, however, not mislead us to suppose that we have to do here with an especial form of decay. As a matter of fact, we are scarcely entitled to speak of such places as decay at all, any more than we are to say that a man with a pockmarked face has got the smallpox, because they do not indicate that the process of decay is going on at the time being. They are simply degenerated tissue, which, in the course of time, has become discolored by oxidation, precipitation, or other processes of this nature. Decay-marks would be a much better name for such spots.

"*b. Decay of Dentine.*—By the progress of the above-described process, the destruction of the enamel spreads until the surface of the dentine is reached. Here the disease takes on a very different form, inasmuch as we no longer find the tissue being changed into a soft, cheesy mass, but into a tough, cartilaginous substance, which does not readily fall to pieces or yield to the slightest friction, as does the decayed enamel, but may retain its form for some time. This stage is designated as softening of dentine, and is conditioned, as will be seen below, by a more or less complete decalcification of the dentine. This softening spreads in all directions in the dentine, with a rapidity dependent upon the intensity of the fermentation processes present in the mouth and the physical and chemical constitution of the dentine.

"The softened mass may be easily cut or peeled off with a sharp instrument; upon pressure, it discharges a small quantity of a liquid which, in the great majority of cases, will be found to redden blue litmus paper,—*i.e.*, to have an acid reaction.

"The thickness of the softened layer varies considerably in different cases. Very soon after the softening of the dentine, its disintegration or dissolution begins, leading to the formation of a cavity in the dentine. The surface now appears uneven, soft, and porous, infiltrated and contaminated with particles of fermenting food, masses of bacteria, etc.

"The discoloration of the dentine is brought about by the same causes as that of the enamel; it also shows the same variations in acute and chronic decay, and all shades from the natural color of dentine to black. . . . .

"*c. Decay of Cement.*—Decay of cement frequently occurs at the neck of the tooth. The layer of cement is, however, so thin here that the characteristic phenomena of cement-caries scarcely become apparent. Caries of the cement of the root occurs only when the latter is exposed, and is therefore comparatively rare.

"The roots of molars which are laid bare by the recession of the gum and destruction of the periosteum show the greatest preference for decay. Such roots are often covered with thick white or yellowish-white deposits, consisting of food-particles, dead epithelium, mucus, and fungus-masses, and not infrequently present cases of typical decay of the cement.

"The first symptom of cement-decay is an abnormal roughness or softness of the cement-surface, which may be easily penetrated or scraped off with an excavator.

"This phenomenon, which is also nothing but the softening of the cement, is followed by a loss of the surface substance; thus a cavity is produced, or rather a depression, since it has little similarity with the cavities of the crown. Deep bulb-shaped cavities are hardly ever formed; they are, for the most part, shallow, widely-extended excavations, without a distinct margin.

"This is due to the fact that there are no circumscribed points of retention or foci of decay on the roots, from which alone the destruction could proceed. It therefore seldom happens that decay, beginning at the root, spreads from the cement to the dentine, and destroys the latter to such an extent that the root-pulp is exposed.

"A natural retention-center is formed at the point of bifurcation of the molar roots, where it has been exposed by recession of the gums, and penetrating decay is consequently not seldom found here. . .

"*Accompanying Phenomena of Dental Decay.*—As concomitant phenomena of dental decay, I designate certain processes which manifest themselves either immediately or some time after the appearance of decay, and which, in my opinion, have been erroneously denominated as characteristics of it.

"These processes are: (1) transparency; (2) the pigmentation or discoloration of the decayed tissue.

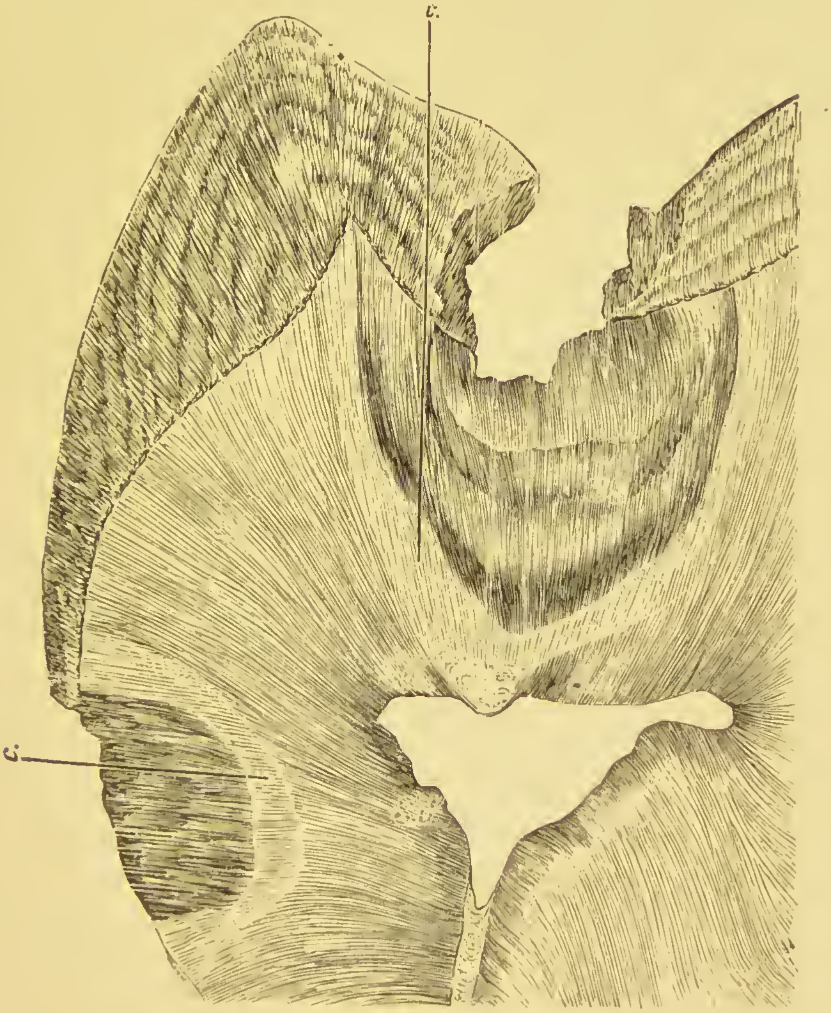
"Coincident with the development of the opacity and the pigmental degeneration in the commencement of the carious affection of the dentine, an increased translucency is observed, frequently, in portions adjacent to the boundary of the carious portion. With reflected light these portions have a horny appearance, similar to that found in senile roots, and with transmitted light they present hyaline bands and spots. The focus of the caries is surrounded by a diaphanous halo. The opaque, carious dental cone, therefore, is invested by a translucent zone, extending from the periphery toward the center; around a more spherical, carious portion of the dentine a crescentic diaphanous halo is sometimes met with. (Fig. 252.) The light portions, finally, vary exceedingly in respect to their outlines, according to the form in which the carious limits are extended, being radiated, kidney-shaped, etc. (Wedl.)

"A true picture of transparency can be obtained only where softening and pigmentation of the dentine have not yet taken place; that is to say, where there is as yet no decay.

"The transparent portion here forms a cone whose apex points toward the pulp, and whose sides run parallel with the dentinal tubules. In most cases the transverse sections of these cones are, as far as my observations go, bounded by two opaque stripes.

"Under the microscope the dentinal tubules within these stripes are seen to be filled with irregular, angular granules or oblong particles.

FIG. 252.



PORTION OF A LONGITUDINAL GROUND SECTION THROUGH THE CROWN OF A MOLAR. Showing two cavities of decay, with the transparent zone at *c*. (After Gysi.)

"*Pigmentation of the Tissue in Dental Decay.*—The pigmentation or discoloration usually attending decay of enamel or dentine is another secondary process, which has erroneously been viewed as a stage of decay. Every degree of discoloration may be observed, from the normal color of the tissue to a yellowish, yellow, yellowish-brown, dark brown, black. In the very first appearance of decay no discoloration is visible. This absence of discoloration is especially remarkable in secondary caries of enamel, the tissue being converted into a perfectly white powder.

"Nor does rapid caries show any, or but very little, discoloration in the deeper parts, while chronic caries always exhibits a dark color, dark brown to black; in other words, the intensity of the discoloration is in inverse proportion to the rapidity of the progress of the disease. Besides, the discoloration of dentine does by no means occur in decay only. Wherever the dentine is laid bare, it may be more or less discolored in time. The black discoloration is especially common in worn-off teeth, and, indeed, not only in the case of smokers, but also of non-smokers, nor is it rare for the teeth of dogs to show a deep brown to black discoloration.

"Most authors concur in the view that the pigment arises from without, and is conditioned by causes which have nothing to do with the decay itself.

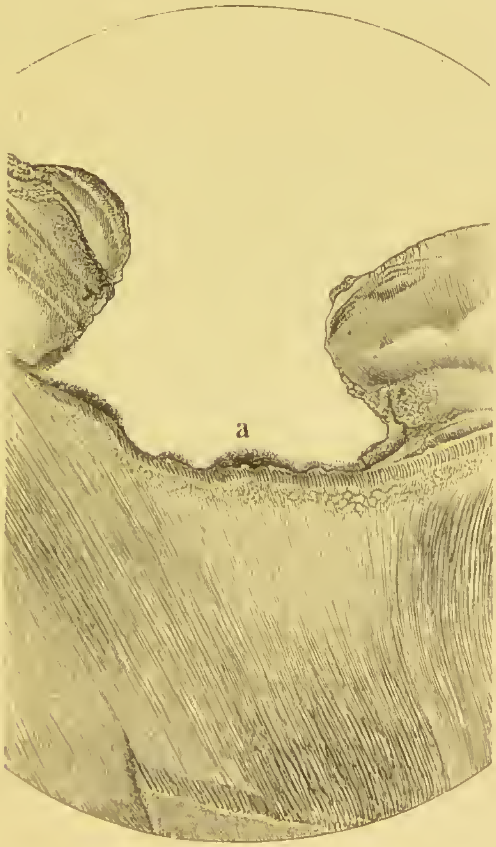
"In my judgment, the cause of discoloration in dental caries is exactly the same as that of the discoloration of any other organic substance which is decomposed by micro-organisms.

"*Decay of Enamel.*—Microscopic examination of decayed enamel brings to light in many preparations nothing more than a depression (a loss of substance), with uneven margins (Fig. 253), a more or less pronounced pigmentation of the enamel in the vicinity of the depression, and a distinct appearance of the transverse striation of the enamel-prisms. In other better-prepared specimens the depression is seen to be filled with masses of micro-organisms which readily take on coloring matter; the margin of the cavity is indented, the enamel cracked, the prisms falling to pieces. The spaces between the loosened prisms are, in these cases, often filled with the same fungal masses, whereas the latter never penetrate between the prisms of normal enamel. In grinding, the masses of bacteria, as well as the loosened prisms, are generally torn away.

"After the enamel has once been perforated by decay, its further destruction proceeds principally from the inner surface. This statement may at first seem strange, but will be found on closer examination to be in accordance with the observed facts. The remains of food accumulating in every dental cavity do not, of course, attack the external, but the internal surface of the enamel. We will find, furthermore, in nearly all large cavities the decay extending from the dentine upon the inner surface of the enamel.

"This latter form of decay, which we designate as secondary enamel-decay, is in many respects better suited for study than the primary, inasmuch as the diseased tissue is not torn away by mastication, etc., and not contaminated from without by foreign bodies.

FIG. 253.

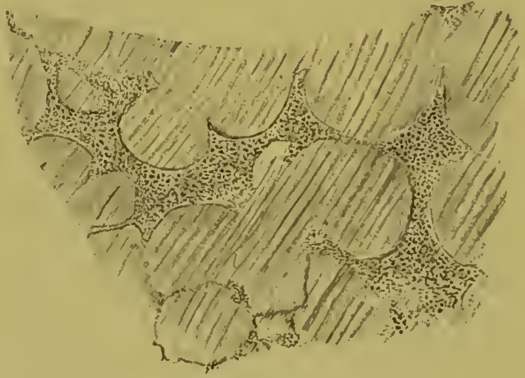


UNDERMINING ENAMEL-DECAY.
a, masses of bacteria lining the cavity. Magnified about 50 diameters.

"Sections of enamel in secondary decay often show the bacteria forcing their way between the loosened prisms. About the same result is obtained where normal enamel is treated with diluted acids. The destruction of the enamel as it occurs in decay must be regarded as essentially a parasitico-chemical process. The loosening of the enamel-prisms is caused by acids, concerning whose origin there can be no doubt; they arise in the mouth by fermentation of carbohydrates. The prisms thus loosened are sometimes mechanically removed; sometimes they remain on the spot, as in the case of secondary enamel-decay, until an opening is formed through which they escape. The bacteria directly participate in the process, inasmuch as they invade the broken-down enamel, perhaps drive the prisms farther apart, and destroy the remnant of organic matter. Micro-organisms do not exert a direct influence on normal enamel; their action upon the enamel in the first stage of decay is therefore indirect,—that is, they act by means of the acids which they produce. In the later stages of the process they exert also a direct action upon the diseased tissue.

"*Decay of Dentine.—Appearances under the Microscope.*—Preparations colored with fuchsin, when examined under very low power or even with the naked eye, show that the bacteria are not equally distributed throughout the mass of softened dentine. Sections parallel to the dentinal tubules (longitudinal sections) generally reveal on the outer margin corresponding to the external layer of dentine a deep-red coloration, which gradually diminishes toward the inner margin. Large tracts of decayed tissue, especially at the extremities of the specimen, often remain entirely uncolored. This necessitates the conclusion that the softening (decalcification) of the dentine extends further than the invasion of the micro-organisms.

Fig. 254.



Interglobular Spaces filled with Micrococci.

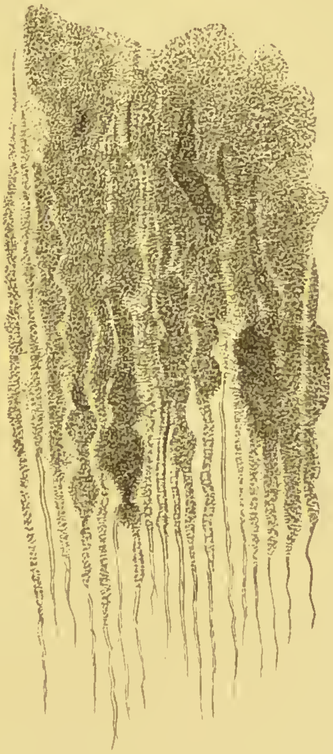
Magnified about 400 diameters.

"Under a somewhat higher power (forty to sixty diameters) we may more easily follow the invasion. Occasionally we find that a majority of the tubules are infiltrated to the same depth;

usually, however, the parasites penetrate the different tubules to very different depths. We also occasionally find that all or nearly all the tubules are filled with bacteria at the surface, while in the deeper parts only a few are infiltrated.

"A question which has often been mooted now arises: Can the bacteria penetrate into normal dentine? This question must be answered in the affirmative. Since the average diameter of the dentinal tubules is greater than that of the bacteria found in the mouth, it is but reasonable to conclude, *a priori*, that bacteria may under certain circumstances make their way into the tubules of apparently intact tissue. Under high power we also often observe that a small number of bacteria, outposts, as it were, have penetrated into the normal dentine, without, however, producing any visible changes.

FIG. 255.



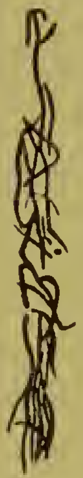
DECAYED DENTINE.

Showing total liquefaction of the basis-substance by bacteria. Magnified 400 diameters.

"In some specimens all the tubules are enlarged to nearly the same extent, occasionally to three or four times their normal size. This enlargement is caused partly by the dislodgment of the neighboring tubules, partly by the loss of the intertubular substance. Lastly, the destruction of the intervening substance causes a confluence of two or more adjacent tubules, producing long caverns running parallel to them. By the formation of caverns and by the fusion of adjacent caverns the dentine is broken up, becomes porous, and is gradually destroyed. The tubules are often attacked in groups, while others lying between these groups may be wholly free from infection. In other cases, however, every single canal is stuffed full of bacteria.

"In Fig. 255 I have endeavored to reproduce an appearance very commonly met with in decaying dentine. This specimen clearly shows that the enlargement of the tubules always found in decayed dentine is due to the infection, and that a gradual fusion of the basis-substance may take place, beginning with the separate tubules, until nothing remains but a mass of bacteria held together by the remnants of the dentine.

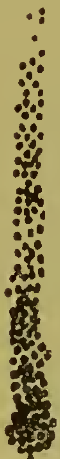
Fig. 256.



Single Tubule.

Filled with thread forms. Magnified 1100 diameters.

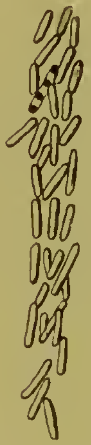
Fig. 257.



Single Tubule.

Filled with cocci. Magnified 1100 diameters.

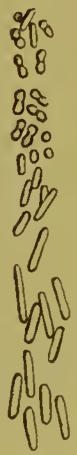
Fig. 258.



Single Tubule.

Filled with rods. Magnified 1100 diameters.

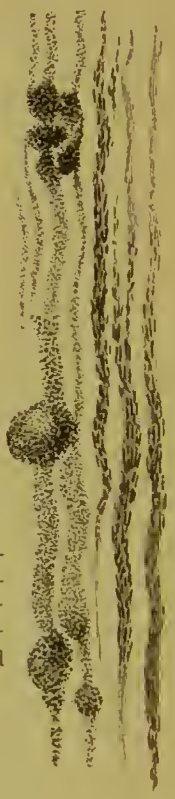
Fig. 259.



Single Tubule.

Showing a mix-infection or infection with a pleomorphous bacterium. Magnified 1100 diameters.

Fig. 260.



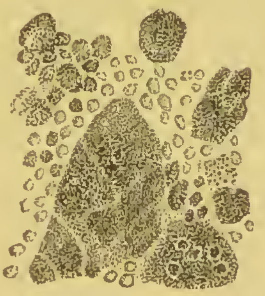
Decayed Dentine.

Showing a mix-infection with cocci and bacilli. Magnified 400 diameters.

"In well-stained specimens the individual cells of the bacteria are clearly visible under a power of 400 to 500 diameters; although for a thorough study of the specimens oil immersion lenses and Abbe's condenser are desirable. With their assistance we see that the external margin of the specimen consists of broken-down dental tissue intermixed with enormous masses of micrococci, bacilli, and leptothrix threads. The latter often appear as fringes on the border of the specimen, but are not found along the entire margin, while in some they are altogether lacking. In many cases, no doubt, they are torn away in preparing the specimens. It is seldom that they penetrate the dentinal tubules, unless the dissolution is already far advanced, and even then they are to be found mostly in the external layers. Tubules containing long, tortuous threads (Fig. 256) are therefore comparatively rare.

"If we examine a somewhat deeper zone, we usually find the tubules filled with micrococci and rods only, the former decidedly preponderating. These two forms of bacteria generally occur in separate tubules; thus we often see a tubule stocked only with micrococci (Fig. 257), the adjacent one only with rods (Fig. 258), while it rarely happens that one extremity of a tubule is filled with rods, the other with cocci.

Fig. 261.



Cross-Section of Decayed Dentine.

Showing the distention of the tubuli and formation of liquefaction-foci. Magnified 400 diameters.

"We have consequently in decay of the teeth to do with a so-called mix-infection (Figs. 259 and 260).

"It is true that we often meet with specimens which appear to contain cocci alone (whether of one or of different varieties the microscopic examination does not tell). On the other hand, I have in my possession a few preparations which exhibit a pure bacillus infection, particularly in circumscribed portions.

"A section cutting the tubules at right angles shows, under a power of 300 diameters, that the tubules filled with micro-organisms are distended from one to four times their normal diameter, and that often two or more of the enlarged tubules are converted into one by the liquefaction of the membranes and the intervening substance (Fig. 261). This melting together of the tubules increases as we near the outer border of the specimen (corresponding to the surface of the cavity), until it is no longer possible to distinguish the separate tubules; we then see only irregular masses of bacteria, of different sizes, which are more or less contaminated by the detritus (*débris*) of the decomposing dentine. These impure masses are what Abbott calls 'embryonic elements.' Since they are not homogeneous they take up the coloring-matter unequally at different points, and therefore occasionally present figures that may bear a certain faint resemblance to cells.

"*Decay of Cement.*—The decalcification and dissolution of the cement proceeds either from the surface inward, in the form of a progressive superficial dissolution of the cement, or the cavities of the cement become infiltrated with bacteria, giving rise to a parenchymatous dissolution, accompanied by phenomena very similar to those of dentine-decay. Its similarity to the latter is especially striking in places where Sharpey's fibers are well developed. Immediately following decalcification these fibers, or rather canals, are infiltrated and enlarged by bacteria which gradually liquefy the intervening tissue. In this way the tissue is rarefied, and finally totally destroyed. I possess several specimens in which this form of cement-caries has been artificially produced.

"When cement-corpuscles are present, they or their offshoots (as far as I have had opportunity to examine such cases) are infiltrated with bacteria and swollen. I was not able to determine any such inflammatory reaction on the part of the cement as occurs, say in bone or cartilage.

"I affirm that a destruction of the tooth-substance may be brought about artificially, which the most practiced microscopist will not be able to distinguish from real decay as it occurs in the human mouth. In fact, not one of the many microscopists who have made the attempt has been able to determine which of a given number of preparations were artificial and which natural.

"I cut up a number of teeth which were perfectly sound, but of different density, into pieces of different size, and placed them in a mixture of saliva and bread. This mixture was for three months at a temperature of 37° C., and during the course of the experiment repeatedly renewed. At the end of this time I showed a number of these pieces to a well-known dentist of thirty-three years' standing, and asked him if these were not peculiar cases of decay. He replied by saying that he saw such cases every day in his practice. In many pieces the dentine was softened through and through, in all to a considerable depth. When the softening had penetrated through the dentine to the inner surface of the enamel, the latter was found covered with a layer of white powder exactly as it is found in natural decay. Cracks and fissures in the enamel had an opaque, whitish appearance, and in many cases could be easily penetrated by a sharp instrument. At the neck of the tooth the dentine was likewise much softened, though not to so great a degree as on the crown. The border of the enamel was rough, and so brittle that in many places an instrument could be inserted between the enamel and the dentine. On the grinding-surface, in such cases where the structure of the tooth was imperfect and full of fissures or depressions, the whole tissue had been converted into a soft mass, such as is often found on the surface of third molars.

"All of the phenomena observed in cases of so-called white decay were present in these cases of artificial decay. If the mixture was allowed to stand until the reaction became alkaline, or if the pieces were exposed to the air or to the action of different articles of food, such as coffee, tea, tobacco, fruit, etc., all possible shades of color were produced just as they are found in the mouth.

"Sections of these pieces showed all the microscopic changes which have been described as characteristic of decay of dentine.

"*The Micro-Organisms of Dental Decay.*—Our knowledge of the micro-organisms most directly concerned in the destruction of the substance of the tooth is as yet very deficient. We have been able to establish the fact that all micro-organisms of the human mouth which possess the power of exciting an acid fermentation of foods may and do take part in producing the first stage of caries; also, that all possessing a peptonizing or digestive action upon albuminous substances may take part in the second stage; and, finally, that those possessing both properties at the same time may take part in the production of both stages. But whether there is any one bacterium which may *always* be found in decayed dentine, and which might therefore be entitled to the name of *the* bacterium of tooth-decay, or whether there are various kinds which occur with considerable constancy, we are not able to say."

From the quotations of Abbott and Miller it follows that the former, although he noticed the micro-organisms in decayed teeth, does not consider them the primary cause thereof. Abbott, however, has accurately observed the tissue-changes in the neighborhood of decay in the enamel, dentine, and cementum. Miller, on the contrary, proved that the invasion of micro-organisms is the only cause of decay; but admits no inflammatory reaction whatsoever in the affected hard tissue of the tooth. In the views of the latter observer, the living tissues are simply destroyed by the micro-organisms without reacting upon the injury.

From my own researches, I am convinced that the full truth in regard to the carious process can be established only by a combination of both Abbott's and Miller's assertions. I admit that micro-organisms are the principal cause of the decay of teeth; but only *dead* material will be destroyed by them without the least reaction. Living tissues—*i.e.*, enamel, dentine, and cementum—invariably react upon the invasion of the micro-organisms by an inflammatory process similar to that in other living tissues, in the manner described by Abbott.

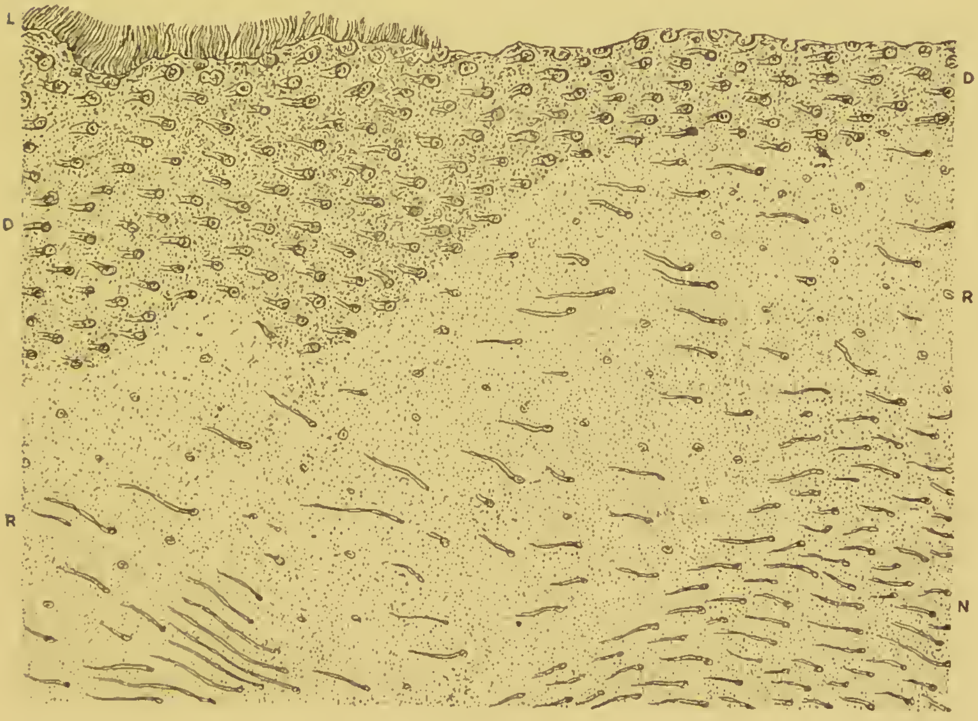
The brown discoloration of the dentine in the neighborhood of decay, of which both authors speak, affords an excellent opportunity for studying the minute structure, especially in freshly-ground specimens. The reticulum, as I have described it in Chapter VIII, is seen here even with medium powers of the microscope. Pigmentation of enamel in the neighborhood of decay likewise furnishes excellent means for studying its minute structure with high powers of the microscope.

Another proof of the tissue-changes in the dentine in the vicinity of decay is the healing process occasionally observed. (See Fig. 262.) Here a recalcification of the softened and probably inflamed dentine has taken place, with a new formation of scanty and irregular canaliculi, such as we frequently observe in secondary dentine. Since all modern researches in biology prove that no new tissue can arise without the previous one being first reduced into an embryonal condition, I do not hesitate to maintain such changes for the living dentine. The difference between the normal and the newly-formed dentine is so conspicuous, especially in the rearrangement of the dentinal canaliculi, that a mere recalcification could never explain these changes.

According to the views thus far explained, I will indicate the changes that occur in the process of caries by the following:

The primary cause of caries is acid fermentation of remnants of food, induced by micro-organisms. The favorable starting-places of caries in the enamel are grooves, pits, and crevices in the surfaces of the teeth, where particles of food are most readily detained. The further progress of caries is due to an invasion of micro-organisms into the hard tissues of the teeth. The result of this invasion is first decalcification and afterward disintegration. Dead tissues are decomposed without reaction. Living tissues, after decalcification, are reduced to an embry-

FIG. 262.



HEALED CARIES OF DENTINE.

L, colonies of leptothrix; *D*, *D*, decalcified dentine, with enlarged canaliculi; *R*, *R*, recalcified dentine, with scanty canaliculi; *N*, normal dentine. Magnified 500 diameters.

onal or protoplasmic condition (Abbott). According to the amount of lime-salts therefor, the constitution of the individual, and according to the number of micro-organisms invading the tissues, the decay is either rapid (acute caries) or slow (chronic caries). In the latter instance a spontaneous healing by a re-formation of the hard tissues is possible. In dentine and cementum acute caries leads to a white discoloration of the tissues involved, while chronic caries frequently causes a brown pigmentation in the neighborhood of decay.

CHAPTER XLI.

THE EFFECTS OF ARSENIC DIOXIDE AND METALLIC ARSENIC UPON THE PULPS OF THE TEETH.—SO-CALLED COAGULATION-NECROSIS.

In 1884 I published* a brief account of experiments with arsenic dioxide, of which the following is an abstract:

The action of arsenic dioxide upon the dental tissues has for a long time been a disputed question, and the changes effected by the poison, when applied to the cavity of a tooth, were thought to be confined to the pulp-tissue. In 1879, A. Witzel, of Germany, published a work on the diseases of the dental pulp. In this he claims that a pulp, if not too much inflamed, can be treated with arsenic dioxide, its coronal portion amputated, and the remaining pulp-stump preserved. This doctrine has created a great deal of controversy in this country, although in Germany it seems to have been almost universally accepted. I have followed this line of treatment in sixteen cases, in an experimental way, selecting teeth which I was able to examine from time to time. The microscopical appearances can best be studied in healthy or superficially decayed teeth of human subjects, or in the teeth of such animals as can be easily experimented upon. In all cases, therefore, a uniform mode of procedure must be adhered to. The line of study being necessarily experimental, has extended over a long period of time, calling for a considerable amount of labor and painstaking care.

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* *Dental Cosmos*, 1884.

The preparation which I have used exclusively is the well-known one composed of one part of arsenic dioxide and one part of sulphate of morphia, made into a paste with chemically-pure carbolic acid, which was put into a drill-hole in the tooth and covered with a temporary stopping. I will not enter into details, but will only mention that, bearing in mind the results I wished to obtain, I drilled in the direction of the pulp-chamber, but did not in any case perforate it. It appeared to be quite immaterial, however, how thick the interposing dentine was in respect to the changes caused by the poison.

I used human teeth and those of rabbits. They were extracted in from three to six days after the application of arsenic dioxide. The teeth were opened immediately after extraction, and immersed without delay in the proper reagent. It is important to proceed in such manner that the pulp shall not be torn or dislodged, and yet may be acted upon by the fluids while still lodged in its natural position. When the elements of the pulp are once sufficiently fixed, it becomes possible to slice it without causing artificial changes. This is no easy matter, for unluckily the hardening fluids most generally in use cause some changes. Even water, and, as has been found, the tissue-fluid itself, if allowed to act a sufficient time after death, gives to the medullated nerve-fibers an appearance which, I have no doubt, has frequently been described as pathological.

After having used different reagents, I have come to the conclusion that the best results can be obtained by immersing the tooth in the manner described in a one per cent. solution of hyperosmic acid for from ten to twenty hours, according to the density of the tooth. As regards the pulp, this will be found to be sufficiently hardened after a sojourn of two to three hours in the same fluid; it can then be easily removed from the pulp-chamber without fear of serious harm. Both parts are then placed in distilled water and preserved in alcohol.

The changes due to the poison are quite pronounced. First, if the poison has acted sufficiently long, the whole of the pulp shows to the naked eye, as soon as exposed, all the signs of active inflammation. According to the degree of inflammation resultant from the irritation which the arsenic dioxide undoubtedly does produce, a greater or less number of nerve-fibers are changed in appearance in such a manner that their myelin is separated into larger and smaller masses, between which I have not been able to distinguish either an axis-cylinder or an intermediate substance. I may, however, mention that I have seen in nerve-fibers, which have remained under the influence of the arsenic dioxide for six days, a granular substance which can be colored by rose anilin, certainly a product of the disintegration of the myelin sheath. I have no doubt that this is a stage toward the complete destruction of the nerve-fibers, and I may mention in this connection that, in one instance, I have found similar globules free in the tissue surrounding a number of degenerated nerve-fibers in an incisor of a rabbit after three days' reaction of the arsenic dioxide.

What will be the result of the arsenic dioxide so applied, not alone to the pulp itself, but in respect to the nutrition and life of the whole tooth, is easily surmised, and can be demonstrated by an examination of the dentine.

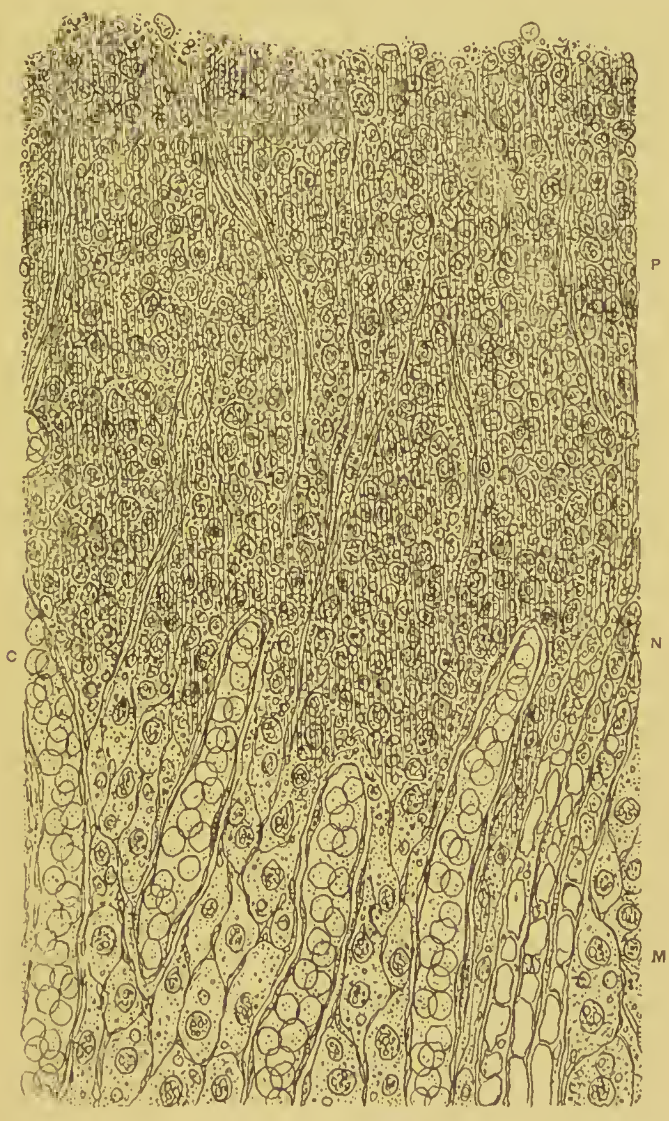
After having treated the newly-extracted tooth with hyperosmic acid, and thereby guarded against artificial changes, I prepared ground specimens of the same. These were then stained with picrocarmin, and suitably treated for mounting. Under the microscope the dentinal canaliculi appear enlarged, more so at one place than at another, and filled with a mass deeply stained in black. The same can be said of the transverse connections of the canaliculi. When, however, high powers are brought to bear on such places, the black mass is found to be composed of irregularly-shaped bodies, which, I doubt not, are remnants of the dentinal fiber. In tracing such canaliculi, it is seen that the swollen dentine-fibers are broken up more and more as one approaches the seat of the greatest destruction. As a consequence, the basis-substance is narrowed in extent as the canaliculi gain in diameter.

Since this publication I have continued my researches on the action of arsenic dioxide, examining the pulps after exposure to the poison for a time varying from twenty minutes to twenty-four hours. The pulps were obtained either after the extraction of the tooth or extirpation by the broach.

The effect of twenty minutes' contact of an inflamed pulp with the poison, in a tooth of a patient sixteen years of age, is illustrated in Fig. 263.

The inflamed zone is conspicuous by the lack of the stain with ammoniacal carmin, which feature we know to be characteristic of the death or necrosis of the tissues. Only the walls of the blood-vessels have taken up the stain, which fact proves that the tissues under the influence of circulating blood retain life longer than those away from the blood-vessels. The inflammatory corpuscles show a peculiar gloss, at the same time lacking sharply-defined contours. The same happened with the tracts of spindles, obviously the remnants of previous blood-vessels. The portions nearest to the non-inflamed pulp and the pulp itself,

FIG. 263.



PULP AFFECTED BY ACUTE PULPITIS TREATED WITH ARSENIC DIOXIDE FOR TWENTY MINUTES.

P, portion of pulp in acute inflammation, showing effect of arsenic dioxide; *M*, normal myxomatous pulp; *C*, capillaries engorged with blood; *N*, bundle of medullated nerves. Magnified 500 diameters.

being of a distinct myxomatous structure, appear colored with ammoniacal carmin. The blood-vessels are dilated and engorged with blood-corpuscles, showing no reaction upon the arsenic dioxide. The medullated nerves are broken up into inflammatory corpuscles in the region of pulpitis. Farther down the myelin is segmented in a manner known to succeed inflammation. Since it seems impossible that arsenic dioxide should have produced an inflammatory reaction within twenty minutes, it is reasonable to say that in this case life was destroyed particularly in the inflamed portions of the pulp. At the same time, the elements had been preserved in size and shape, and therefore were mummified.

C. Weigert* has proposed to term such a condition of tissues and elements "coagulation-necrosis." This term seems to be applicable whenever heat or chemical reagents, such as strong solutions of corrosive sublimate, carbolic acid, chloride of zinc, etc., are brought in contact with the tissues, combustion of the skin and mummification of the pulp being good examples. Serious doubts have been raised by good observers against the propriety of the term "coagulation-necrosis" as proposed by Weigert.

In a number of pulps treated with arsenic dioxide from one to twelve hours, no evidence of necrosis of the pulp-tissue could be obtained, since the stain with ammoniacal carmin was present and the appearance of mummification absent. An instance of diffuse calcification of the pulp with complete mummification from arsenic dioxide after twenty-four hours' contact is illustrated in Fig. 264. This pulp was removed from an upper central incisor of a patient about sixty years of age. The crown was half worn away by mechanical abrasion, nearly approaching the pulp-chamber. The application of arsenic dioxide was made for the purpose of devitalizing the pulp in order to obtain sufficient anchorage for a large contour gold filling. The pulp was extracted by means of a broach. Under the microscope a large portion of the pulp was found diffusely calcified. The pulp-tissue still showed vestiges of structure, though finely granular throughout. Most of the capillary and venous blood-vessels were found crowded with clusters of irregularly-outlined blood-corpuscles of a dusky red-brown color. The perivascular space around these vessels was widened and well pronounced. The medullated nerves, some of which entered the calcified region without having caused pain, were broken up into small, glossy, irregularly-shaped lumps, the same

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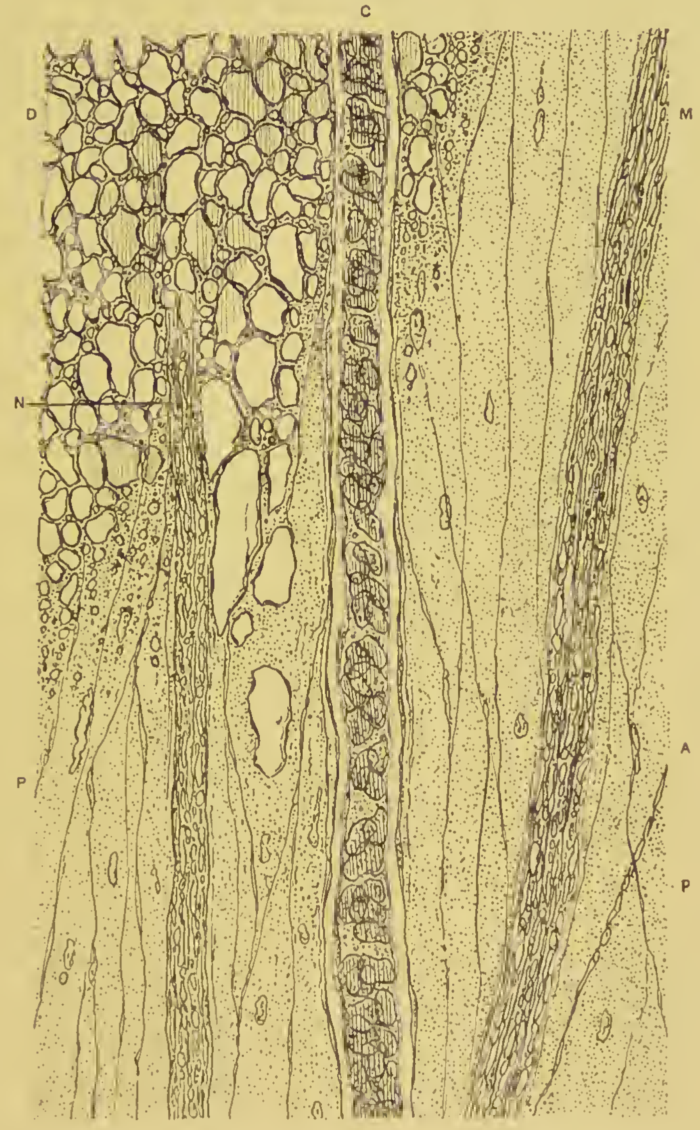
* *Deutsche Med. Wochenschr.*, 1883.

Fig. 264.



Pulp affected by Calcification treated with Arsenic Dioxide for Twenty-four Hours.

D, diffuse deposits of lime-salts; *N*, bundle of medullated nerves, entering the calcified portion of the pulp; *M*, bundle of medullated nerves, broken up by arsenic dioxide; *A*, axis-cylinder, changed by arsenic dioxide; *C*, capillary holding changed red blood-corpuscles; *P*, *P*, finely-granular pulp-tissue. Magnified 500 diameters.

as non-medullated nerves, still traceable here and there. This feature is long since known to me as a result of the action of arsenic dioxide.

In the highest degrees of mummification, when the reagent has been left *in situ* for several days, the pulp-tissue is transformed into a yellowish-red, glossy, almost waxy-looking mass, in which the tissue-elements are but faintly recognizable.

My experience with arsenic dioxide has led me to consider it an unreliable agent, often causing the death of the pulp in circumscribed regions, mainly of the coronal portion, leaving the root-portions unaffected. But even in such instances the root-portions are liable to die, and subsequently become a source of suppurative pericementitis. In some cases no reaction whatsoever follows the application of arsenic dioxide; in others only pulpitis is brought forth, instead of mummification; in still other cases the action is too far-reaching, and destroys the whole of the pulp, the crown as well as the root-portions. Exceptionally the inflammatory reaction is so severe that pericementitis sets in, and instances are on record in which extensive gangrene followed the application of arsenic dioxide.

My advice in regard to the use of arsenic dioxide for the purpose of devitalizing the pulps of teeth is to employ it only in exceptional cases, and, if possible, discard it altogether. When, however, it is made use of, this should only be done in normal or in *acutely-inflamed* pulps. In all cases of chronic pulpitis, and especially in hyperplasia of the pulp, arsenic dioxide should never be applied. In the latter instances it is liable to produce a very acute attack of pulpitis, accompanied by excruciating pains, and usually without the desired result of devitalizing the pulp.

In order to obviate the difficulties of filling pulp-canals, Wilhelm Herbst, of Bremen, Germany, recommended a novel procedure.*

The methods of practice observed by him are as follows: If the pulp of a tooth is in such a condition that it becomes necessary to remove it, an application of cobalt,† to which has been added about eight per cent. of hydrochlorate of cocaine, is made to it, and covered with wax or some other temporary filling-material. After two or three days the temporary filling is removed, the cavity cleansed from all decay, and rinsed out with water. Then, if practicable, the rubber-dam is adjusted, the cavity thoroughly disinfected, and the coronal portion of the pulp is amputated by means of a large, perfectly clean, sharp, round bur, which is rapidly revolved in the hand-piece of the dental engine. The bur must be nearly as large as the coronal portion of the pulp which is to be amputated. The pulp-chamber is then to be washed out with a solution of corrosive sublimate of the strength of one-tenth of one per cent., and dried. A cylinder, or a loosely-rolled ball of No. 4 tin foil, as large as the cavity will admit, is now placed in the pulp-chamber directly over the amputated pulp-stump, and with a revolving, smooth burnisher, which is smaller than the pulp-chamber, the tin is burnished firmly into it. In burnishing, care should be exercised not to press the tin directly upon the pulp-stump, but the force should be exerted more laterally. It is also necessary that the stumps to be capped in this manner be not irritated with small burs, excavators, or nerve-instruments, as failure has been observed in those cases in which this was done. Herbst also advises that in case the tooth becomes sensitive to pressure after such an operation, it should be shortened a little, and the filling in the tooth not left high enough to touch the antagonizing tooth. If amalgam is employed, it is advisable to place a small particle of wax upon the tin cap, and distribute it over the surface of the tin by means of the rotat-

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* "The Herbst Method of Treating Pulps." *Dental Cosmos*, 1892.

† A sample of cobalt, sent by Dr. Herbst, was examined by Dr. E. C. Kirk, who found it to be metallic arsenic.

FIG. 265.

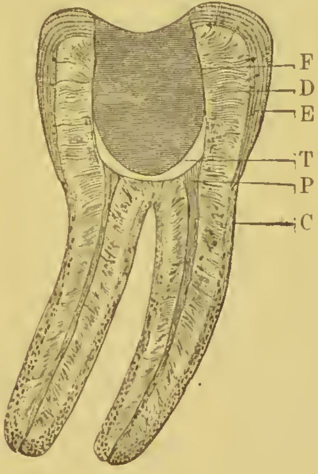


DIAGRAM OF MOLAR TREATED BY DR. HERBST.

F, filling; *D*, dentine; *E*, enamel; *T*, tin cap over pulp-stumps; *P*, pulp; *C*, cementum.

ing burnisher. If this precaution is neglected, the mercury of the amalgam will combine with the tin, and the efficiency of the cap be destroyed.

The theory entertained by Herbst in regard to this treatment of pulps is that by burnishing tin or gold into the pulp-cavity, he creates an absolutely air-tight covering to the root-canal, which is not obtainable with other materials. Herbst claims that good results cannot be expected by the use of amalgam, cement, or gutta-percha, and even tin and gold foils introduced into the pulp-chamber by the mallet system have proved to be failures. In cases of front teeth, he employs gold foil instead of tin,—as he claims, with equally good results.

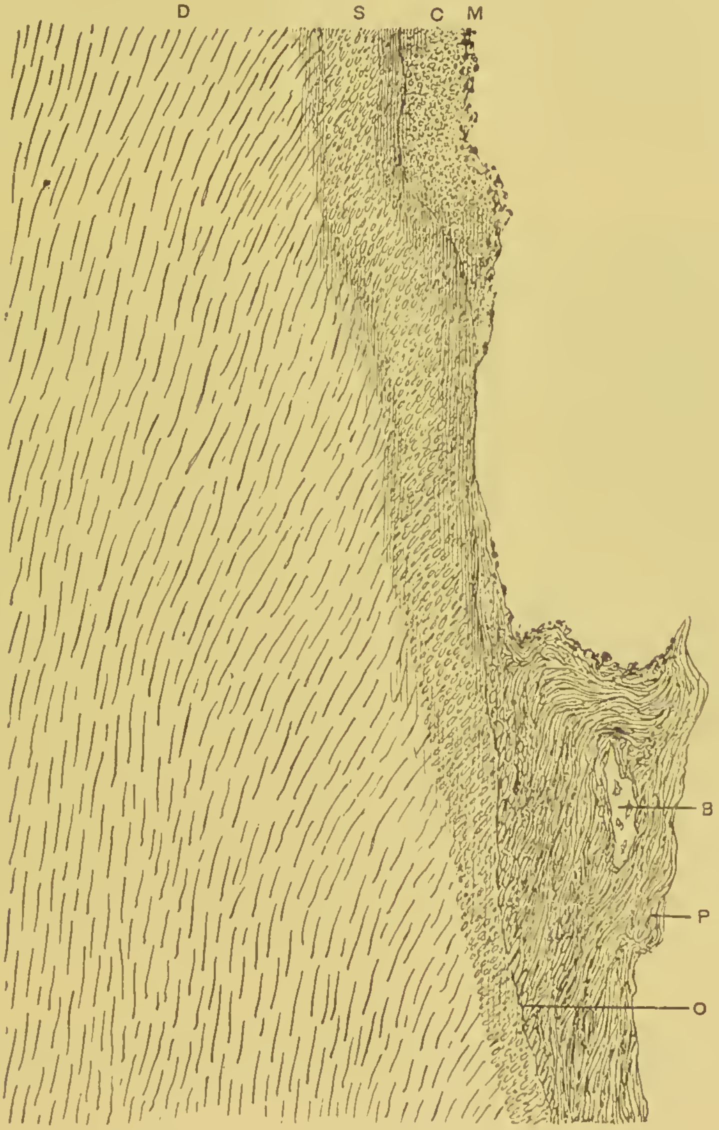
One of the teeth, an inferior molar, which Dr. Herbst sent to me for examination, was amputated and capped by him in the manner above described about three years ago, and had been in a normal condition until it was extracted. The tooth was removed on account of an overcrowded condition of the dental arch, as well as to obtain a specimen for examination. Immediately after extraction it was immersed in dilute alcohol, in which it was sent to this country. Upon its arrival here it was placed in a solution of chromic acid of the strength of one per cent., which solution was renewed every day until the dentine became sufficiently soft to be sliced by the microtome. For staining, an ammoniacal solution of carmin, and for mounting, glycerin, were employed.

A longitudinal section through the crown and one of the roots of this tooth yielded an image as depicted in Fig. 266. In the pulp-cavity of the crown we see remnants of a narrow zone of previously-inflamed, necrotic tissue. The outermost border of this layer is conspicuous because of the presence of black metallic particles, probably the tin foil in combination with sulphur. At the point of bifurcation the pulp is preserved, though changed into a fibrous connective tissue by the process of chronic plastic pulpitis.

In this fibrous pulp we observe small spiculæ of bone-tissue. The boundary zone between the pulp and the dentine shows narrow rows of calcified elongated corpuscles, similar to those which we often observe along the border between the cementum and pericementum of the neck and the roots of normal teeth. The border of the pulp, toward the pulp-cavity, which had been filled with tin, is likewise marked by metallic particles, which proves that the tin actually has been in contact with the pulp-tissue.

The border of the dentine, both in the crown and the root, is of considerable interest. In the crown the dentine toward the necrotic pulp is thoroughly calcified, without a pronounced structure, evidently in the condition of consolidation and aug-

Fig. 266.



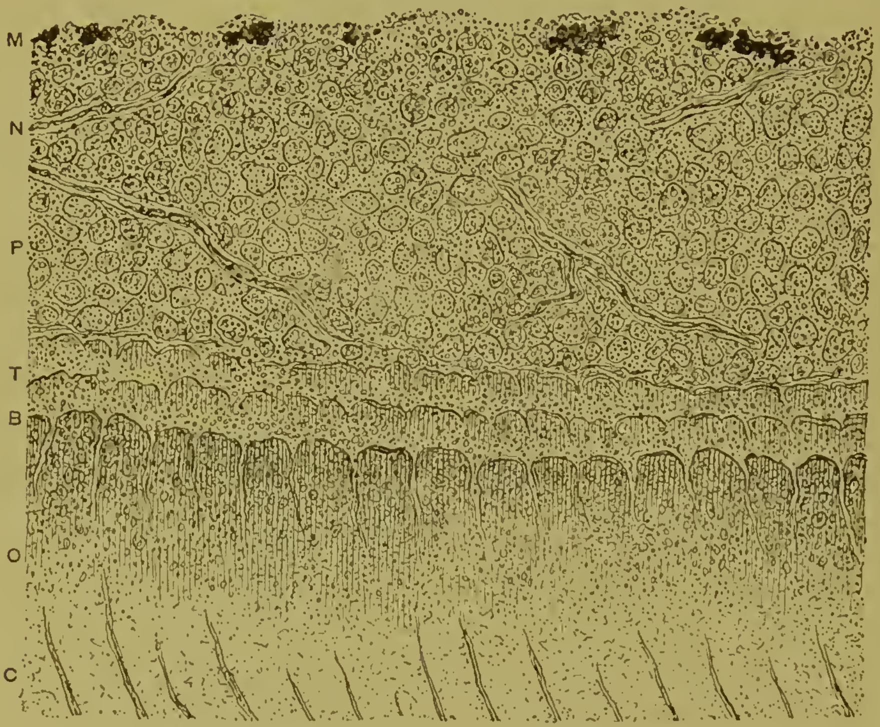
Section of Lower Molar Border of Pulp-Chamber, near Bifurcation of Roots.

D, dentine, canaliculi cut obliquely; *S*, secondary changes of dentine; *C*, colonies of micrococci in dead pulp; *M*, black particles of metal; *P*, fibrous pulp, the result of chronic plastic pulpitis; *O*, osteoid layer of pulp at the border of dentine; *B*, spiculæ of newly-formed bone. Magnified 100 diameters.

mented deposition of lime-salts, such as we often observe in dentine bordering metallic fillings. All along the pulp-canal the dentine is broken up into small globular and oblong corpuscles, obviously the result of a previous acute eburnitis, with subsequent deposition of lime-salts. This peculiarly altered zone of dentine is broadest along the pulp-chamber of the crown, and gradually tapers along the pulp-canal of the root, while toward the apex it altogether disappears.

A portion of this wall of the pulp-chamber of the crown is

Fig. 267.



Border of Pulp-Chamber of the Crown.

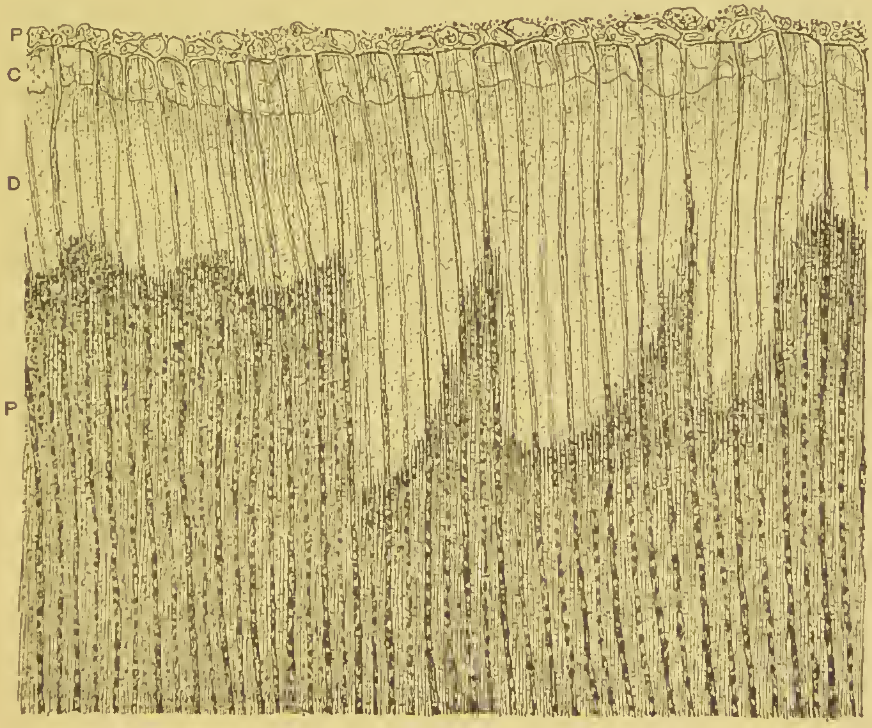
M, black particles of metal at the surface; *N*, necrotic vestiges of non-medullated nerves; *P*, necrotic remnants of the pulp; *T*, thickness of specimen, successive layers of dentine; *B*, border of dentine, with gaping dentinal canaliculi; *O*, region of obliterated dentinal canaliculi; *C*, pointed ends of dentinal canaliculi. Magnified 500 diameters.

illustrated in Fig. 267. Here we observe a layer of necrotic pulp-tissue, with metallic particles at the outermost periphery. The pulp, before it became necrotic by the action of cobalt, must have been in a condition of intense acute pulpitis, which is proved by the presence of numerous vestiges of inflammatory corpuscles. The necrotic pulp shows even remnants of non-medullated nerve-fibers, likewise in a granular disintegrated condition.

In some of my specimens, in the dead pulp I could trace colonies of micrococci, developed during the process of pulpitis, and deprived of life and rendered innocuous by the application of cobalt and contact with the tin.

In that portion of dentine depicted in Fig. 267 a zone is missing. The dentine borders the dead pulp in an abrupt line, conspicuous by regular, though widened and funnel-shaped, dentinal canaliculi. It seems probable to me that the widening of the canaliculi is the result of an acute pulpitis, which did not last long enough to induce pronounced changes in the tissue of the dentine. The border zone of the dentine is granular, and followed by a zone of consolidation in which the dentinal canaliculi have completely disappeared. Possibly the whole border of the dentine toward the necrotic pulp is devitalized down to the region in which dentinal canaliculi and unchanged dentinal fibers are observed. The pulp of the crown, however, is

Fig. 268.



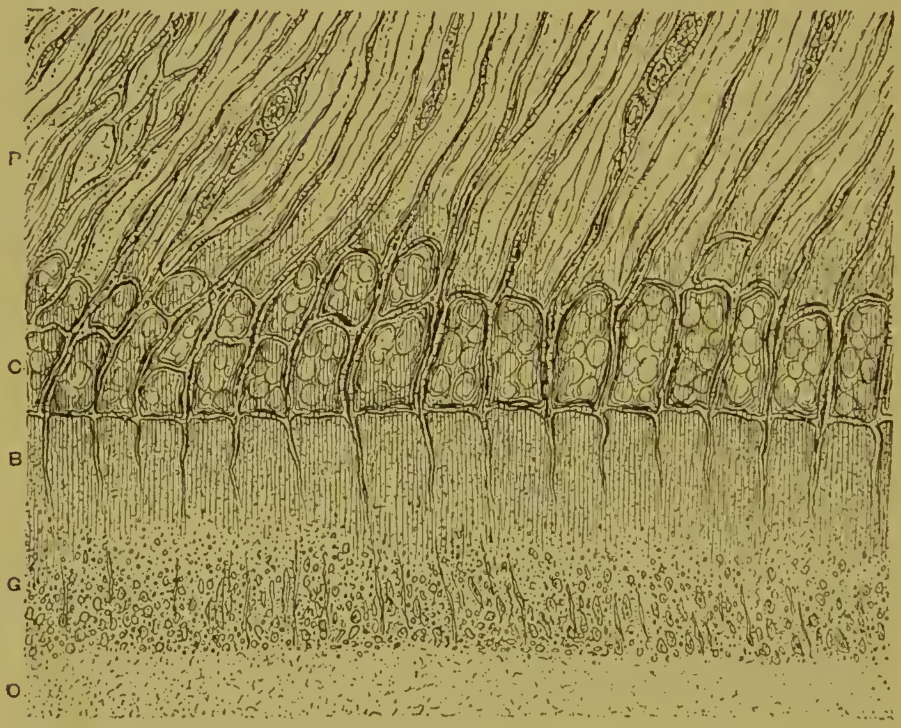
Border of Pulp-Chamber of the Crown.

P, protoplasmic layer of inflamed pulp; *C*, zone of consolidation of dentine; *D*, dentine with canaliculi without deposits; *P*, dentine in which the canaliculi are loaded with metallic particles. Magnified 500 diameters.

not altogether necrotic; there are portions within the crown still supplied with a narrow layer of living pulp, as shown in Fig. 268.

These vestiges of the pulp are broken up into protoplasmic bodies, which in part have become the seat of calcareous deposits. The only way to explain this remarkable feature is that a thin film of the inflamed pulp has escaped both the process of cauterization with cobalt and destruction by the amputation. The zone of dentine nearest to the pulp is consolidated, as shown by its high refraction under the microscope; but even this consolidated portion is pierced by unchanged dentinal canaliculi holding normal dentinal fibers. The dentine along the pulp-chamber of the crown in many instances exhibits a peculiar black discoloration, which I have often observed in dentine that has been in contact with an amalgam filling. Strange as it may appear, it is nevertheless a fact that the discoloration does not start from the border of the dentine, but a certain distance

FIG. 269.

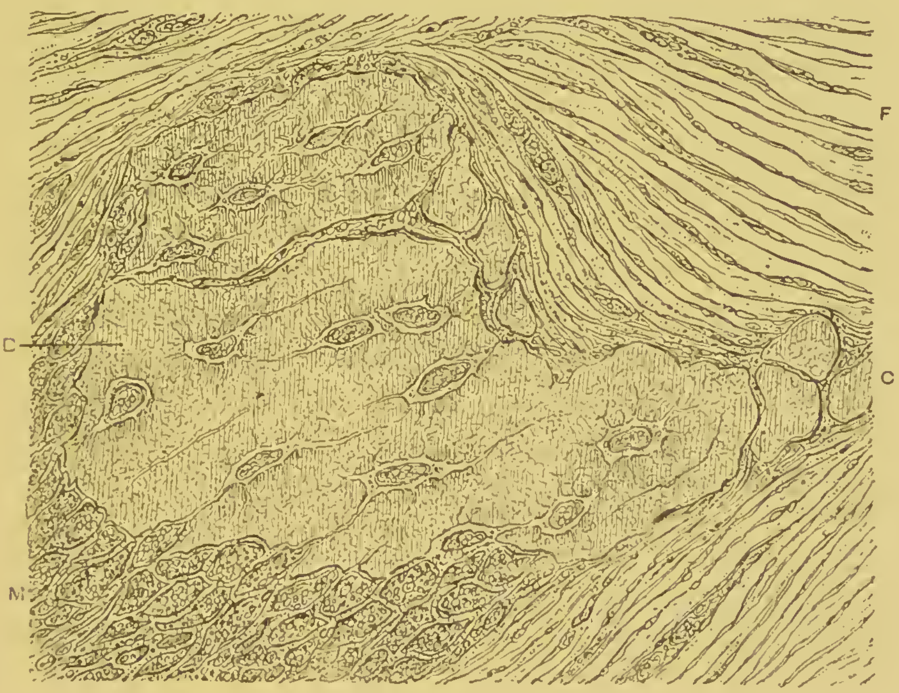


BORDER OF ROOT-CANAL.

P, fibrous pulp, the result of chronic plastic pulpitis; *C*, calcified layer of pulp; *B*, border of dentine; *G*, granular layer of dentine; *O*, layer with obliterated dentinal canaliculi. Magnified 500 diameters.

away from it. As shown in Fig. 268, the discoloration is caused by the presence of metallic particles, lying as if arranged in rows within the dentinal canaliculi, and by the diffused brown pigmentation of the basis-substance between the canaliculi. The latter color is most intense in an abrupt line, irregular in itself, toward the pulp-chamber. The peculiar discoloration is explicable only by admitting a transportation of metallic particles by the dentinal fibers, a strong proof of the life of both the dentinal fibers and the basis-substance of the dentine.

Fig. 270.



Ossification of Fibrous Pulp.

F, coarse bundles of fibrous pulp, derived from chronic plastic pulpitis; *B*, spicula of bone, with bone-corpuscles; *C*, calcification of pulp-tissue preceding ossification; *M*, medullary tissue. Magnified 500 diameters.

I have stated before that the pulp of the root-canals, beginning from the point of bifurcation, is transformed into fibrous connective tissue. The nature of this transformation is rendered clear by higher powers of the microscope. (See Fig. 269.)

The pulp-tissue is really made up of bundles of fibrous connective tissue, almost as broad as those of pericementum, periosteum, or the derma of the skin. Between the bundles we notice interstices of varying breadth filled with protoplasm, as we always observe in formations of fibrous connective tissue. The bundles toward the dentine terminate in calcified, elongated clusters, corresponding on an average with the breadth of the bundles themselves. The most striking feature is that the interstices between the calcified lumps and the bundles above these lumps contain fibers similar to dentinal fibers. The border of the dentine toward the fibrous pulp is slightly consolidated,—that is, somewhat richer in lime-salts than the rest of the dentine. This consolidated layer is followed by a granular one, which is scantily provided with lime-salts, containing vestiges of dentinal canaliculi. Next follows a layer of dentine in which the dentinal canaliculi are obliterated, which a little farther away appear with pointed ends holding normal fibrillæ.

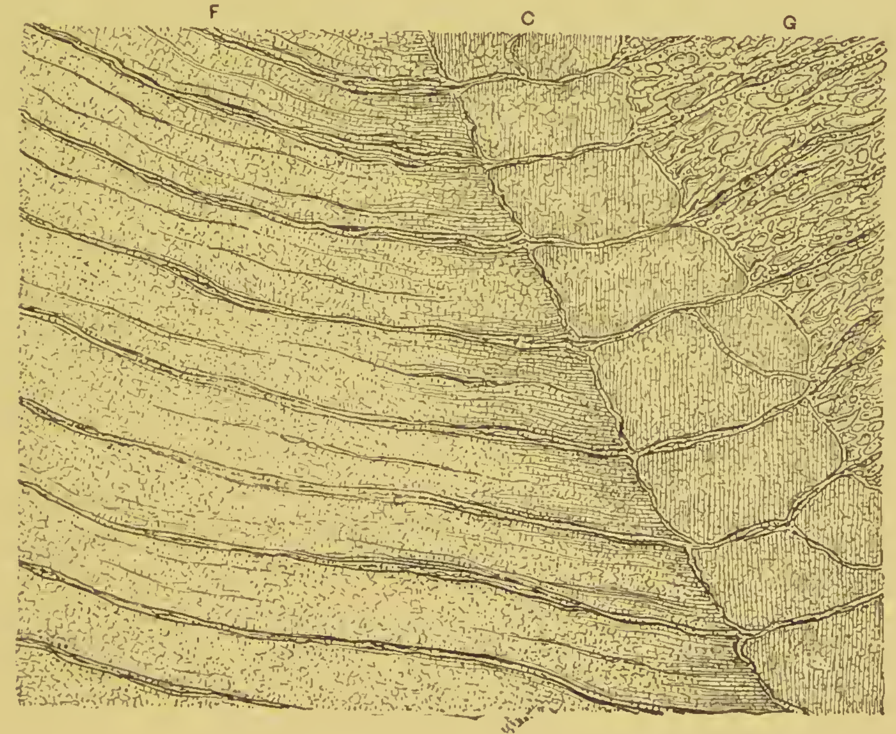
In Fig. 266 is illustrated a small spicula of bone in the pulp-tissue, which is of considerable interest when studied with higher powers of the microscope. (See Fig. 270.)

Here we observe normally developed bone-tissue, but lacking Haversian canals and regular lamellæ. We also see the manner in which bone-tissue is developed from the fibrous connective tissue of the pulp. This is accomplished by the intervening formation of a medullary or embryonal tissue (see *M*), from which the bone-corpuscles, as well as the basis-substance of the bone-tissue, are forming. The formation of bone is not of uniform progress all around this spicula, as we observe a bordering of the bone by a fibrous tissue, in some places unchanged, in others slightly reduced to protoplasm. The transformation of the medullary into the bone-tissue is not always an immediate one. In some places we notice calcified groups of medullary corpuscles (see *C*) preceding ossification. Unquestionably the lime-salts of such clusters must be dissolved out again before the final appearance of the bone-tissue proper.

The microscopical analysis of this molar is of considerable biological importance. The dentine was found alive, its fibers unchanged throughout the crown and the roots, except a narrow zone which bordered the portion of necrotic pulp. This result is explicable only by the fact that the pulp of the roots, although changed in structure, is still alive. The proof of this assertion is furnished by examining the specimens with high powers of the microscope, as seen in Fig. 271.

We observe all the bundles of the fibrous connective tissue traversed by a delicate reticulum, without resorting to any special staining process. This reticulum of living matter inosculates with the protoplasm between the bundles, and with the fibers which appear like dentinal fibrillæ in the interstices between the bundles. A similar reticulum is noticeable in the consolidated as well as in the granular layers of the dentine. Obviously, the living pulp of the roots, assisted by the nutrition derived from the pericementum, kept the dentine of the whole tooth alive. If the dentinal fibers in the canaliculi were the only living formations of the dentine, nothing but the dentine of the roots could have remained alive after the destruction of the coronal portion of the pulp in the crown of the tooth. Since, however, the whole of the dentine has remained alive, we have another strong proof of interconnections between the dentinal fibers. These interconnections are established by the delicate reticulum of living matter pervading the basis-substance of the dentine.

Fig. 271.



Border of Dentine of Root toward the Pulp.

G, granular layer of dentine; *C*, thoroughly-calcified layer of dentine; *F*, fibrous pulp made up of coarse bundles. Magnified 1000 diameters.

Another lower molar was sent to me by Dr. Herbst. It had remained in the mouth about eighteen months after the pulp had been amputated and capped in the manner before described. The tooth had given no trouble since the operation, and was extracted for the same reason as the one described above.

This tooth was not decalcified in a solution of chromic acid, but split into several pieces by excising forceps, and ground thin upon a corundum-wheel in the lathe, constantly keeping it under an aqueous solution of table-salt.

The roots of this tooth contained but a narrow mass of pulp-tissue, crowded with globular deposits of lime-salts, and in the process of formation of secondary dentine. The latter was found developed all along the walls of the root-canals in a heavy mass, interposed between the primary dentine and the remnants of pulp-tissue. It consisted of the most common variety,—viz, wavy and irregular canaliculi, traversing the basis-substance. The production of such secondary dentine from the pulp-tissue of the roots is a strong proof of the life of the pulp, which, having been irritated less than the tooth first described, directly led to the formation of secondary dentine.

In conclusion, I would advise to remove the pulps from those roots which we know can be prepared easily, and treat them in the manner we have been accustomed to, but amputate and cap the others.

CHAPTER XLII.

NECROSIS OF THE JAW-BONES.

Whenever purulent pericementitis sets in, there is danger of the inflammation spreading to the adjacent periosteum and causing necrosis or death of the jaw-bone. In previous years the idea prevailed among pathologists that by the intense inflammatory infiltration of the periosteum the blood-vessels were compressed and rendered unfit for carrying nutrient material to the jaw-bones. To-day we know that the discontinuance of blood-supply is not due to a compression of the vessels, but to a breaking up of the walls of the blood-vessels first into inflammatory, afterward into pus-corpuscles. As shown in Chapter XXXIX, the capillaries and veins become obliterated by a proliferation of their endothelial coat; the same holds good for small arteries, the endothelia here being involved first, and followed by inflammation of the muscle-coat. As soon as a breaking asunder of the inflammatory into pus-corpuscles takes places, all vestiges of such blood-vessels disappear.

If, in a certain area, the blood-vessels in the periosteum and in the medulla of the bone are destroyed, life of the bone ceases; or in other words, the bone-tissue corresponding to the extent of the bloodless area becomes necrotic.

In the mildest cases of purulent periostitis, the wall of the alveolus, or portions thereof, may become necrotic. In severe cases the body of the jaw-bone may die; in the worst instances the purulent periostitis suddenly or gradually attacks the whole jaw-bone, especially the lower one. Not infrequently life is endangered by the spreading of the suppuration from the upper jaw-bones to the base of the skull, with subsequent purulent meningitis and encephalitis. From the lower jaw the inflammation may extend into the mediastina, causing abscesses, purulent pleuritis, pericarditis, etc. Another source of fatal termination is the formation of pyæmic abscesses in the lungs, the liver, etc. All these terminations were far more common in tissues when asepsis was unknown, and cases are on record in which the extraction of a tooth with an unclean pair of forceps had sufficed to produce purulent or septic periostitis of the jaw-bone, with subsequent pyæmia and the death of the patient in a comparatively short space of time. To-day aseptic precautions being used by all intelligent dentists and surgeons, such accidents have become great rarities.

Staphylococcus (aureus, albus, and citreus) is known to be the cause of suppuration, if invading an already-inflamed tissue. A rapidly-progressing suppuration easily terminates in gangrene of the inflamed periosteum, so-called "*gangrène foudroyante*" of the French, which probably is caused by a mixed infection with staphylococcus and streptococcus septicus, of which latter as yet little is known.

Besides purulent pericementitis, the most common cause of necrosis of the jaw-bones in previous years was the inhalation of the vapors of phosphorus in match-factories. It is an established fact that only the workers with carious teeth were exposed to purulent periostitis. Since the introduction of ventilation and other sanitary measures, and since the care of the teeth is stringently carried out in match-factories, the so-called phosphorus-necrosis has become of rare occurrence. Purulent pericementitis is, however, of common occurrence, and in every instance a source of possible purulent periostitis and necrosis of the jaw-bones.

Diagnosis.—Necrosis manifests itself by the sensation of roughness, when a probe or another suitable instrument is brought in contact with the bone. The surface of dead bone always is denuded of periosteum, and consequently appears rough, similar to the surface of a piece of wood sawed across its grain, while normal bone to the touch of an instrument is smooth like velvet. A diagnosis of the extent of the necrosis cannot be established either by the probe or by the naked eye. The gum and the periosteum over necrosed bone always appears inflamed, detached from the bone, and upon pressure pus oozes forth. One of the principal characteristics of the presence of necrotic bone from local origin is that pus forms continually, even though the original source of irritation be removed. In such cases, local treatment is sufficient for a cure. When the necrosis is depending upon constitutional derangements, such as syphilis or tuberculosis, etc., it will subside only upon a combined constitutional and local treatment.

Subjective Phenomena.—In mild cases of local necrosis of the jaw-bones the patient suffers no pain, the only annoyance being the constant flow of pus from the fistulous opening. The teeth which produced the trouble may be still involved in the inflammatory process, but, although loose, they cause no pain. In extensive cases, however, especially those depending upon syphilis, tuberculosis, or the inhalation of the vapors of phosphorus, the patient may suffer pain, if the inflammation involves either the superior or the inferior maxillary branches of the fifth pair of nerves. Besides this, the constant discharge of fœtid pus often causes a derangement of the digestive organs, and consequently of the general constitution. The necrotic process, if extensive and acute, invariably is accompanied by intense swelling and pain of the affected region and by high degrees of fever. In a slowly-progressing purulent periostitis only the swelling and dull pains may be conspicuous, without a pronounced febrile derangement.

Differential Diagnosis.—There is but one disease with which necrosis of the jaw-bone may be confounded,—viz, chronic alveolar abscess. In most of the cases of local origin, chronic alveolar abscess is associated with or followed by the necrotic process. In the beginning of the necrosis an examination by means of the probe will always clear the diagnosis.

The prognosis of necrosis of the jaw-bones largely depends upon its extent, its acute or chronic course, and the general constitution of the patient. The dental practitioner, if called upon to treat such a case, is in a great measure responsible for the final favorable or unfavorable termination. The pus pours forth from the sockets around the roots of the teeth, and the latter soon become loose. Some practitioners are in the habit of extracting all such loose teeth, with the view of furnishing free exit to the pus and checking the progress of the disease. This practice is not always advisable, since we know that loose teeth after the removal of the sequestrum (necrotic bone) have become firm again by being implanted in the newly-formed bone-tissue produced by the remnants of periosteum, and serve for mastication again, at least for a number of years.

I have seen many cases of partial necrosis of the jaw-bones from purulent periostitis induced by a root of a tooth. In one instance, that of a lower molar, the two roots were laid bare by necrosis of a portion of the socket, while the lingual portion of the root remained firm and rendered the tooth serviceable for twelve years, when at last it was destroyed by caries.

Conservative surgery is decidedly in place in every case of necrosis. No surgeon is able to find out the limits of the disease until nature has circumscribed the process. Chiseling, drilling, nor treatment with aromatic sulphuric acid will ever check the process. After a complete sequestration of the central necrotic bone, the opening of the newly-formed ossified case is an easy matter, and we know that after so-called necrotomy of the whole lower jaw-bone a fairly well-formed new jaw-bone may be produced, with most of the teeth preserved. (J. R. Wood.)

A. Lorinser, of Vienna, about fifty years ago, was the first to accurately describe the necrosis of the jaw-bones from phosphorus-poisoning. From a large experience in these cases, he strictly urged the so-called conservative plan of treatment. Recently he found support by E. Rose, of Berlin,* for all cases of inflammations terminating in necrosis of the jaw-bones. This author claims that the teeth may be saved even when held in place only by the gums, and are wiggling like the stalks of wheat in the wind, the roots being perfectly bare. He asserts that the life of the teeth may remain preserved through the attached gums. In this he unquestionably is mistaken. The serviceability of the teeth, after their impaction in newly-formed bone, does not depend upon their life, but upon their firmness. The final conclusions of his article are as follows: "In all inflammations of the lower jaw of a dubious nature, we will hereafter preferably make the incision from below, to save the gums at all events; chisel all bone-cases of the jaw from the lower surface, and extract the dead jaw, as it were, from the teeth. The wiggling of the teeth never ought to induce us to their hasty extraction. We thus will be rewarded by having all teeth fixed in the newly-formed jaw, useful as ever."

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* "Das Leben der Zähne ohne Wurzeln." *Deutsche Zeitsch. für Chirurgie*, Bd. XXV, 1887.

The histology of necrotic bone I have published many years ago.* As to the microscopical differences between normal and necrotic bone, the successful study of the elements of bone-tissue much depends upon the method employed. I have followed the methods of examination of bone-tissue after decalcification in solution of chromic acid. This enabled me, by the use of the razor, to obtain sections fit to be examined by an immersion-lens magnifying 800 to 1000 diameters. I noticed that the canaliculi could be plainly seen in sections, the basis-substance of which had retained a small quantity of lime-salts; in completely-decalcified specimens they are but faintly discernible. According to my experience, it is better to stain the sections with a solution of chloride of gold of the half of one per cent., whereby a better view of both protoplasm and basis-substance is obtained. Another good way is to stain the sections with carmin and hæmatoxylin.

The results of my observations with high magnifying powers are that the bone-tissue presents faint parallel lines, dividing it into the so-called lamellæ, within which we find the bone-corpuscles of varying shapes. As bone-corpuscles are flattened lenticular bodies, we will recognize them in this shape in the front view only. Longitudinal sections through these bodies give a spindle-shaped outline, small when cut near the boundary, broad when cut through the middle line of the lentil.

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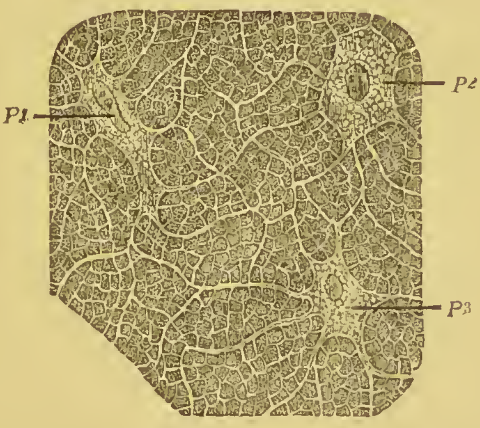
* "Necrosis." *Dental Cosmos*, 1877.

A cross-section through a bone-corpuscle shows a somewhat irregular body. A cross-section from the compact bone of a lower jaw presents invariably bone-corpuscles in all three varieties.

Fig. 272 shows three bone-corpuscles, from the lower jaw of a man about thirty years of age, who died of an aneurism. All three bone-corpuscles are drawn in the front view.

We see three large spaces, showing a number of ray-shaped offshoots. Besides these coarse offshoots, innumerable extremely fine light ones are present. The larger as well as the smaller ones interconnect by this delicate net-work throughout the basis-substance. Within the three lacunæ are present protoplasmic bodies. We observe in the center of the protoplasmic bodies P^1 and P^2 a shining oblong nucleus in P^1, and a round one in P^2, in which the nucleoli are not distinctly visible. Around the nuclei we see a narrow seam, traversed by numerous fine conical threads. Their bases are directed toward the nucleus, from the periphery of which they arise, while their points are in connection with the nearest granules of the protoplasm. Within the protoplasmic substance there are finer and coarser granules, all being interconnected by fine threads. The seam around the nucleus, as well as the spaces between the meshes of the threads, are observable, being much lighter than the latter.

Fig. 272.



Normal Bone-Tissue of the Lower Jaw of a Man aged Thirty Years. Chromic Acid Specimen, Stained with Chloride of Gold.

Three bone-corpuscles: P^1, with an oblong nucleus; P^2, with a globular nucleus, both exhibiting indistinct nucleoli; P^3, with a small compact nucleus. Magnified 1000 diameters.

From the periphery of the protoplasmic body numerous thick offshoots enter the larger canaliculi, which sometimes can be followed up until they communicate with the other large neighboring canaliculi. Besides these, many delicate offshoots run from the periphery of the protoplasm contained in the larger canaliculi toward the basis-substance. Some of them can be seen to enter the fine canaliculi, but their course cannot be distinctly followed. *P*³ shows a protoplasmic body without nucleus; probably this has been cut near to its periphery without touching the nucleus. Though I am not able to demonstrate the presence of living matter in the finest canaliculi, yet, as we find it in all other kinds of connective tissue, I am justified in assuming it. In normal bone the lacunæ and canaliculi are not entirely filled by the living protoplasm. At the periphery of each protoplasmic body we see a distinct light seam, traversed by the offshoots, which in a cross-section only show the living part of the protoplasm in the center of the canaliculus, hence leaving sufficient space for the nutrient circulation.

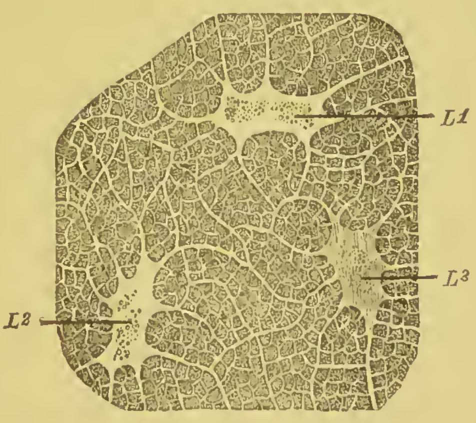
The minute changes of necrotic bone are highly interesting, but it is impossible to study the difference between it and normal bone in specimens prepared from dry osseous tissue.

The methods employed were exactly the same as before described from normal bone. The necrotic sequestra, as soon as they had been taken from the mouth, were put into the solution of chromic acid, and cut in due time. Some I stained with chloride of gold, some with hæmatoxylin, and some I mounted unstained.

The results of these examinations were as follows:

The outer surface of the necrotic bone, which, to the naked eye, looked rough and eaten out, when brought under the microscope showed bay-like excavations, known formerly as "Howship's lacunæ," in which there was visible a granular mass mixed with pus-corpuscles. In the middle of the bone I found all the Haversian canals more or less enlarged, some showing the bay-like excavations. The contents of the Haversian canals were everywhere the same,—a conglomerate mass of darkly-shaded granules, which I was unable to stain with carmin; therefore micro-organisms, such as we see in decomposition of organic matter,—"micrococci." Here and there some medullary corpuscles and multinuclear protoplasmic bodies (myeloplaxes of Robin, giant-cells of Virchow) were recognizable. I did not see blood-vessels in any of the Haversian canals. In the necrotic bone I found the traces of former osteitis. The enlargement of the Haversian canals and lacunæ is direct proof of this; the dissolving out of the basis-substance on the periphery may, on the contrary, have been due to chemical changes, produced by infiltrations from the neighboring inflamed tissues. Billroth has shown that if pieces of bone or ivory are driven into living bone, in which they excite inflammation, they will afterward exhibit a peculiar dissolution of basis-substance analogous to that which we see in the primary stage of inflammation. The Haversian systems and concentric lamellæ were unchanged. The lacunæ and canaliculi were yet preserved. In preparations from the necrotic lower jaw I observed many lacunæ, in which the protoplasmic body, with its living net-work, was yet distinguishable, especially where the sequestrum had been attached to the periosteum. I found also, in specimens from the necrotic upper jaw, some comparatively unchanged bone-corpuscles. But the majority of the bone-corpuscles, and especially in the neighborhood of the Haversian canals, were either empty, or their protoplasmic bodies were shriveled up (probably the remains of the living matter), only showing a few coarse granules, illustrated in Fig. 273; but no signs of fatty degeneration could be seen, for the granules were stained violet by chloride of gold. Many lacunæ showed no structure at all, the

FIG. 273.



NECROTIC BONE-TISSUE OF THE LOWER JAW OF A WOMAN AGED THIRTY-EIGHT YEARS. CHROMIC-ACID SPECIMEN, STAINED WITH CHLORIDE OF GOLD.

Three lacunæ: L^1, with two clusters of a granular mass; L^2, with scanty granules; L^3, with a nearly homogeneous mass. Magnified 1000 diameters.

contents looking rather like a mass of coagulated albumin. In none of these lacunæ was the characteristic structure of protoplasm recognizable.

To sum up my observations, I found,—

First. The lacunæ of normal bone contain a protoplasmic body, with a net-like arrangement, to be regarded as the living matter of the protoplasm.

Second. The basis-substance is pierced by numerous coarse and fine canaliculi, communicating with one another, as well as with the lacunæ.

Third. The protoplasmic bodies, which do not quite fill the lacunæ, send offshoots of the living substance into the canaliculi, but can only be seen in the coarser ones.

Fourth. In necrotic bone, traces of former osteitis are visible, but no blood-vessels in the Haversian canals, which are filled with micrococci.

Fifth. In necrotic bone, most of the lacunæ contain no protoplasm, but either a coarsely-granular or a structureless mass,—remnants of the living matter and coagulated albumin.

CHAPTER XLIII.

EMPYEMA OF THE ANTRUM.

This term implies a chronic inflammatory condition of the mucous membrane lining the antrum, and an accumulation of serum and mucus mixed with more or less pus in the cavity. The disease may originate from a catarrhal condition of the lining membrane of the nasal cavities; chronic alveolar abscess; chronic hyperplastic diffuse pericementitis; or cystic formations. The teeth most liable to cause empyema antri are the second upper bicuspids and the first molars; although any tooth of the upper jaw, by protracted purulent inflammation, may induce the disease. While an alveolar abscess or hyperplastic pericementitis may be present for a long period without causing empyema of the antrum, sometimes the antrum becomes affected in a comparatively short space of time, due to constitutional disturbances, such as scrofula, anæmia, chronic diseases of the kidneys or the liver, tuberculosis, etc. In many instances, empyema of the antrum has been confounded with cystic formations or myxomata, so-called "polypi," developed in the antrum, or its immediate vicinity. Sometimes, as Zuckerkandl mentions, cysts fill the entire cavity of the antrum, and simulate the symptoms of empyema antri. Such cysts have probably been the cause of terming the disease under consideration "hydrops antri." The ailment, therefore, can only be called "empyema antri" when the accumulated secretion is derived from the lining membrane. In this condition we find the mucous membrane of the antrum considerably swollen and spongy. The communication between the antrum and the nasal cavity ("ostium maxillare") in light attacks usually is preserved, while in severe cases it often is found to be temporarily closed. In quite chronic cases, however, the ostium maxillare may be found completely obliterated; although this may also occur in consequence of the formation of polypi in the hiatus semilunaris (Zuckerkandl). When the ostium maxillare is closed, the facial plate of the antrum becomes more or less extended, often causing considerable disfigurement of the patient's face.

Diagnosis.—The principal characteristic of empyema antri is a catarrh of the mucous membrane of the affected side of the nose, accompanied by a peculiar disagreeable odor. The nasal catarrh is quite pronounced if the ostium maxillare is open, and in these instances the accumulated secretions of the antrum flow out freely when the patient occupies the recumbent position resting upon the unaffected side of the face. When the ostium maxillare is closed the face shows more or less swelling, and the facial plate of the affected antrum easily gives way upon pressure, producing the peculiar crepitation similar to that of parchment. In severe cases the eye protrudes from its socket, and the nasal cavity becomes obstructed in consequence of the bulging of the nasal wall of the antrum. A characteristic feature of this swelling is the absence of fluctuation. By placing the index finger of one hand on the palatine surface under the antrum, and the index finger of the other hand upon the facial portion over it, by alternating pressure we are sometimes enabled to produce a movement of the contents of the antrum. In these instances the bony palatine wall of the antrum has likewise been absorbed, and crepitation upon pressure is present.

Since the majority of antrum troubles are caused by diseased teeth, the principal attention should be directed to the examination of every tooth in the upper jaw of the affected side. As a rule, the offending tooth is easily detected by its color, as well as its sound upon percussion, because such teeth invariably are devitalized. When the ostium maxillare is closed, we sometimes notice a slight protrusion of the second bicuspid and first and second molars, usually outward, although the teeth may appear comparatively firm in their sockets. If the offending tooth is situated under the antrum, we are frequently enabled to obtain entrance to the antrum through the pulp-canal by means of a fine long nerve-broach. The result of this procedure is the evacuation of a large quantity of a badly-smelling fluid. The gums, though more or less inflamed, seldom show fistulous openings, unless extensive necrosis be associated with the disease under consideration. Transillumination by means of a small electric mouth-lamp usually yields the most satisfactory results in the diagnosis of empyema of the antrum. This method enables us to notice the slightest hypertrophic as well as catarrhal condition of the mucous lining of the antrum.

Subjective Phenomena.—In the incipient stage empyema antri may present the symptoms of acute purulent diffuse pericementitis, and cause considerable pain, swelling of the face, and fever, which, however, seldom lasts longer than from two to three days. This is followed by a period of an uneasy sensation, though the tooth has remained quite sensitive to the touch; the pain and swelling of the face, as well as the general symptoms of fever, mostly having abated. The patient usually becomes affected with more or less headache and earache, and sometimes with more or less neuralgia of the affected side of the head. By the constant discharge of fœtid pus, either through the nasal cavity or directly into the mouth, the patient's general health becomes noticeably affected. Sometimes the mucous membrane of the nose is infected, and ulceration, so-called ozæna, is the result. In one instance the author has observed an extensive eczema of the affected side of the face in consequence of a severe empyema antri. In exceptional cases the patient notices a clicking sound in the affected antrum, upon turning the head from one side to the other. This sound is said to be similar to that produced by a closed bottle half filled with water, when the bottle is suddenly inverted.

Differential Diagnosis.—Empyema of the antrum may easily be confounded with ozæna of the nose, cysts, or polypoid growths.

Empyema of the antrum is easily differentiated from ozæna; as in the latter disease the catarrh and ulceration are present in both nasal cavities, while in empyema antri the catarrh only involves one side of the nose. Uni- or multilocular cysts, when located in the alveolar process at the base of the antrum, are not easily diagnosed, especially when they are large. A characteristic feature, however, of a large cyst developed into the antrum is that the inner (nasal) wall of the antrum seldom bulges into the cavity of the nose, and as long as the cyst is intact no secretion or odor can be noticed in the corresponding nostril. Furthermore, the walls of a cyst of the alveolar process usually are hard and unyielding, while those of the antrum affected with empyema sometimes are yielding to pressure.

When a cyst occupies the cavity of the antrum, the ostium maxillare appears closed, unless the wall of the cyst becomes ruptured. The formation of a cyst in the antrum always is slow, extending over a period of many months, and its development never is accompanied by fever or other systemic derangements.

Myxomatous tumors, so-called polypi of the antrum, according to Zuckerkandl* are found in two forms,—viz, those containing glands, and others without them, corresponding to the irregular distribution of glands in the mucous membrane of the antrum. This author is of opinion that some of the polypi containing glands degenerate into cysts (Cysten-Polypen). Such polypi are richly supplied with blood-vessels, and upon the slightest injury by an instrument introduced into the antrum bleed profusely, which fact is characteristic of their presence.

The prognosis of empyema antri largely depends upon the general constitution of the patient, which when good will greatly enhance the cure of the disease. Should the trouble be caused by purulent pericementitis, the tooth must be sacrificed at once. In most of these instances, however, there is present, besides the empyema of the antrum, more or less necrosis of the alveolar process or jaw-bones, which must be removed before the mucous membrane of the antrum can be successfully treated. This having been accomplished, the communication between the mouth and the antrum in a healthy person usually obliterates within one to four weeks, providing that the mucous membrane of the antrum has reached a normal condition. Empyema antri in consequence of an infection from the nasal cavities, in most instances abates by the treatment of the nasal cavity, and does not strictly belong to the sphere of dentistry.

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* "Die Normale und Pathologische Anatomie der Nasenhöhle." Wien, 1892.

CHAPTER XLIV.

THE CLINICAL AND ANATOMICAL FEATURES OF TUMORS IN GENERAL.

Definition.—Whenever new tissue is formed at the surface of the body, in the walls of its cavity, or in internal organs, we designate it as a tumor, provided the augmented bulk of tissue is not caused by inflammation. The best definition of a tumor ever made is that of A. Lücke,[*] who claims that an inflammatory new formation is of a limited course, and even suppuration terminates with cicatrization; whereas the augmentation of a tissue caused by a tumor has no physiological termination, therefore grows indefinitely.

Etiology.—The cause of the growth of a tumor, as a rule, is a local slight irritation, often repeated or continuous. In previous years the term "disposition" was resorted to, to explain the appearance of tumors. Obviously, this term did not explain anything. J. Cohnheim[†] established the theory that malignant tumors always originate from germs misplaced at the earliest period of development, which theory has proven fallacious. The celebrated surgeon Langenbeck,[‡] of Berlin, has demonstrated that so-called gummy tumors of the tongue often become cancerous. This observation alone is sufficient to overthrow Cohnheim's theory. In many instances we are at a loss to explain the origin of tumors. It is always the safest way to confess ignorance instead of promulgating wrong theories.

Growth, Benignity, and Malignity.—Although the properties of the tumors concerning their innocuity or malignity are strictly of a clinical value, they are of the utmost importance to the oral surgeon, in order to advise his patient whether a tumor is harmless, not endangering life, or whether the removal of the tumor is an absolute necessity to preserve life. The points of differentiation are as follows:

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[*] Chirurgie von Pitha und Billroth. Art. Geschwülst.

[†] Allg. Pathologie.

[‡] *Archiv. f. Klin. Chirurgie*, 1875.

Pain.—Benign tumors, as a rule, are not painful, unless exposed to mechanical injuries. Cavernous angioma and neuroma are an exception to this rule, since, although of a benign type, they are painful often in a high degree.

Demarkation.—Benign tumors appear, in the majority of cases, sharply circumscribed to the eye, as well as to the touch with the point of a finger. Their borders are easily defined, the tumors often being inclosed in a capsule, which renders them movable. Malignant tumors, on the contrary, are always infiltrated, designating that they lack a distinct border, but diffusely blend with the adjacent tissues. It is exceptional that a malignant tumor is ensheathed by a capsule and circumscribed to the touch.

The growth is not always decisive. Some benign tumors, especially if inflamed, may grow rapidly; whereas malignant tumors may exceptionally make slow progress. On an average, however, it is true that benign tumors grow slowly; the malignant ones, on the contrary, rapidly. A benign fibroma requires years before it attains a conspicuous size, say that of a hazelnut: while a sarcomatous or cancerous tumor may reach such a size within one year, eventually within a few months.

The covering skin or mucosa will remain movable, even pliable, over a benign tumor, unless inflammation should lead to its fixation. Malignant tumors almost invariably soon become infiltrated into the tissues of the skin or mucous membrane, which renders them immovable. This symptom may be missing if a heavy aponeurotic layer be interposed between the tumor and the surface.

Reaction upon Adjacent Tissues.—Benign tumors, growing slowly, cause no irritation or inflammation of the neighboring tissues, especially no increase in the size of the adjacent lymph-ganglia. Malignant tumors always cause irritation in their environments, and especially cancerous tumors will, sooner or later, cause a swelling of the lymph-ganglia in the vicinity, due to an invasion of the lymphatics with cancer-epithelia and a transformation of the lymph- into cancer-tissue. Sarcomatous tumors do not always attack the lymph-ganglia, though they are tumors of a malignant type.

Ulceration of the Surface.—Benign tumors will ulcerate only if subjected to an improper treatment with caustics. Otherwise it is a rare occurrence for benign tumors to ulcerate in consequence of their weight and pressure exerted upon the covering skin or mucous membrane. Cancerous tumors invariably will ulcerate sooner or later, owing to a local sloughing from obliteration of blood-vessels. Such ulcers are crateriform, with sharply-raised borders, of an uneven, as if corroded, base, lacking granulations, and never discharging pus copiously. The dried pus frequently produces a crust over the ulcer. In such cases the practitioner should beware of forcibly removing the crust or pressing hard upon the tumor. A. G. Gerster has shown that by such rough treatment cancer elements are driven into the lymphatics, thereby causing a rapid infiltration of the neighboring lymph-ganglia, as well as a rapid spreading of the disease. Sarcomatous tumors likewise may ulcerate on the surface, producing smooth, raw surfaces, discharging but little pus. For sarcoma, however, an ulceration is not the rule, as is the case in cancer.

Infection of Remote Tissues and Organs.—Benign tumors may be present in large numbers over the surface of the body, or scattered in internal organs. They will never cause an impairment of the general constitution, and never be multiplied by being disseminated through the blood or lymph-vessels. Malignant tumors will, sooner or later, debilitate the organism and produce secondary tumors of their own kind in internal organs, mainly the lungs, the liver, and the kidneys; though there is no organ of the body exempt from the appearance of secondary deposits. The name given to such a dissemination of malignant tumors (sarcoma and cancer) is "metastasis." To-day we know that it is a carrying away of particles of the primary tumor to distant organs, especially those provided with a narrow capillary net-work. Here the dragged-off particles lodge by a process called embolism and thrombosis. Wherever particles of a malignant tumor are wedged into a normal tissue or organ, a new tumor will be produced at the expense of the surrounding tissue, which is directly transformed into the type of the tissue of the tumor. Sarcomatous tumors are disseminated mainly by the system of blood-vessels; cancer tumors mainly through the lymphatics. Sometimes the last-named tumors are disseminated through the lymphatics in a retrograde manner,—

i.e., opposite to the current of the lymph. The secondary tumors, in the majority of cases, possess the properties of the original one. Exceptions to this rule are cases in which a rapidly-growing cancer causes the appearance of secondary nodules in the lungs, the liver, etc., with all characteristics of sarcoma; lacking, therefore, the epithelial structure of carcinoma altogether. About fifty years ago, R. Virchow* already established the fact that intensely malignant and rapidly-growing cancers change into sarcoma. Later researches have fully corroborated this statement of the great German pathologist.

Diagnosis.—In many cases of tumors the recognition of their nature is not difficult. In others the clinical features may not be so pronounced as to warrant a diagnosis. In such cases the microscope is called upon to decide dubious questions, provided that the microscopist himself is an experienced and conscientious observer. A wedge-shaped piece, the size of a pea, is cut out of the tumor, the hemorrhage being checked by the liquor sesquichloride of iron. The excised piece is placed into a fifty per cent. alcohol, or, preferably, into a fifth of one per cent. solution of chromic acid. After two days' hardening the tumor is ready for examination with the microscope, first being sliced into thin slabs by means of a razor.

The main question to be decided by the microscope is, Is the tumor of a benign, suspicious, or malignant type? Again, in the majority of instances, the microscope is able to give a definite answer to the above questions. The features upon which decision is possible are simple enough. The more basis-substance is present between the protoplasmic bodies, the so-called cells, the more certain it is that the tumor is benign. The more crowded, on the contrary, the protoplasmic bodies, the less, therefore, the basis-substance, the more certain it is that we have to deal with a malignant tumor. In the worst types of malignant tumors the basis-substance is completely absent. A mixture of these two features will render the tumor suspicious, necessitating an early extirpation.

Even a well-versed microscopist may meet, exceptionally, with difficulties in determining the nature of a given tumor. For instance, it is difficult to differentiate between a subacute inflammatory process of the fibrous connective tissue and a fibro-sarcoma; the latter being usually diffuse, the former scattered in the shape of inflammatory nests. It is impossible to differentiate between the tissue of a syphilitic gumma and a highly malignant lympho-sarcoma, because both are made up of similar elements. Neither the clinician nor the microscopist alone should rely with absolute certainty upon their findings. Coöperation of both is, as a rule, necessary to reach a correct final diagnosis.

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* *Archiv. f. Path. Anat.*, 1843.

Prognosis.—A tumor of the benign type will grow slowly and cause disfigurement of or discomfort to the patient, but will not endanger his life, unless vital functions, such as mastication, deglutition, etc., be interfered with. Repeated hemorrhages may considerably debilitate the constitution. The removal of such tumors is left to the judgment of the surgeon. Quite different is it with suspicious or malignant tumors, the removal of which is an urgent necessity on account of the dangers involved by a rapid local growth, by ulceration, by repeated hemorrhages, by the infiltration of neighboring lymph-ganglia, and the production of secondary tumors in distant parts. The sooner such tumors be removed, the better are the chances of a permanent cure. Again, the question, whether or not a tumor is operable, sometimes is left altogether to the judgment of the surgeon.

Classification.—C. Heitzmann in 1879* issued a system of classification of the tumors, entirely based upon histological principles. This system is simple and comprehensible. According to the four main varieties of basis-substance of connective tissue, the myxomatous, the fibrous, the cartilaginous or chondrogenous, and the osseous, he arranges the benign connective-tissue tumors proper as follows:

1. *Myxoma* or *mucoid tumor* (so-called polypoid tumors of mucous membranes).
2. *Fibroma* or *fibroid tumor* (hard, painless tumors to be found anywhere in the connective tissue).
3. *Chondroma* or *cartilaginous tumor* (hard, smooth, or lobulated tumors met with in the bony system, the lungs, etc., of rare occurrence).
4. *Osteoma* or *bony tumor* (hard, globular, or pointed growths found upon the skeleton; rare).

The embryonal or medullary condition of the connective tissue furnishes a malignant type:

5. *Myeloma* or *sarcoma*. The term "sarcoma" proposed by Vir-

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* "Microscopical Morphology." New York, 1883.

chow is objectionable, since it implies a fleshy tumor (*σαρχ*, flesh), whereas myeloma means what these tumors in reality are,—*i.e.*, medullary tumors. The main types are: the *globo-myeloma* (round-celled sarcoma of Virchow), and *spindle myeloma* (spindle-celled sarcoma of Virchow). Such tumors are of a white color, the so-called encephaloid of old authors, or more or less pigmented *melanotic myeloma.*

The combination of connective tissue with fat, with a large amount of blood-vessels, with smooth muscles, and with nerves, provides four other benign varieties of tumors:

6. *Lipoma* or *fatty tumor* (common in the subcutaneous, rarer in the submucous tissue).

7. *Angioma* or *vascular tumor.*

Such tumors consist either mainly of newly-formed blood-vessels, being common in the mucous membrane of the oral cavity, or of newly-formed lymphatics, rarities in the tissue of the skin.

8. *Myoma* or *muscular tumor* (most common in the walls of the uterus, rarer in the skin).

9. *Neuroma* or *nerve tumor* (rare, exceedingly painful tumors, met with in the skin and the central nervous organs).

Any one of these eight benign tumors may combine with the type of myeloma furnishing the so-called dubious, or suspicious tumors, which according to the admixture of the varieties of connective tissue are termed myxo-myeloma, fibro-myeloma, chondro-myeloma, and osteo-myeloma; according to the amount of fat, blood-vessels, smooth muscles, or nerve-fibers, lipo-myeloma, angio-myeloma, myo-myeloma, neuro-myeloma. Such combinations invariably show a tendency toward malignancy, and tumors of this type are rather prone to recur after extirpation.

The combination of connective with epithelial tissue results in the production of two varieties of benign tumors:

10. *Papilloma*, or *warty tumor*, in which the epithelium furnishes the outer investment of the tumor (common on the skin, comparatively rare on mucous membrane).

11. *Adenoma*, or *glandular tumor*, in which the epithelia produce regular glandular formations of the acinous or tubular variety, often combined with cysts.

The great majority of *cysts*, being lined at the inner surface with epithelia, are secondary formations of adenoma. Glandular tumors may be built up, aside from the epithelial formations, of myxomatous or fibrous connective tissue. If the connective tissue be in an embryonal or medullary condition, we speak of an adeno-myeloma. This combination is rare in comparison with the transformation of adenoma into carcinoma. Cystic cavities may occur in any of the benign tumors, but not being lined with epithelia, should not be termed cysts proper, but serous accumulations, indicated by the addition of the word hydro; such as hydro-myxoma, hydro-fibroma, etc. (W. Freudenthal.)*

The combination of connective tissue with epithelium intermixed in the shape of solid nests, plexuses, pegs, or imperfect tubular, gland-like formations, establishes the malignant type of—

12. *Carcinoma* or *cancer.* If small groups of epithelia are surrounded by, and intersected with, a large amount of dense, fibrous connective tissue, this form is termed "*scirrhus.*" If epithelial pegs, holding concentrically arranged nests, in the centers of which we find glossy colloid lumps (so-called "cancer pearls"), penetrate into the connective tissue, we speak of "*dermoid cancer*" or "*epithelioma.*" The presence of tubular glands means the adenomatous preliminary stage of carcinoma, which form is dubbed "*adenoid cancer.*" If epithelial nests are abundant, lacking regularity, we have before us the worst type, —*i.e.*, "*medullary cancer.*" The connective tissue around the epithelia often exhibits glossy corpuscles of the size and aspect of lymph-corpuscles. The more numerous such corpuscles the more malignant is the cancer, and the more rapidly it grows. Virchow termed this feature "small cellular infiltration;" Waldeyer, "inflammatory infiltration." Heitzmann has proven that the corpuscles under consideration present the earliest stage in the development of cancer-epithelia. If, after extirpation of a cancer, the cut surface exhibits such corpuscles, ever so few in number, we can with certainty expect a recurrence of the cancer.

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* "Two Nasal Polypi." *Archives of Ophthalm. and Otology.* 1893.

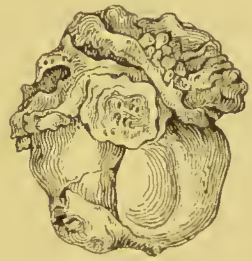
CHAPTER XLV.

TUMORS OF THE TEETH.

THE majority of tumors of the hard tissues of the teeth are congenital. All of them are of a benign type, and either stationary or of an extremely slow growth. The only known tumor of the pulp is malignant myeloma.

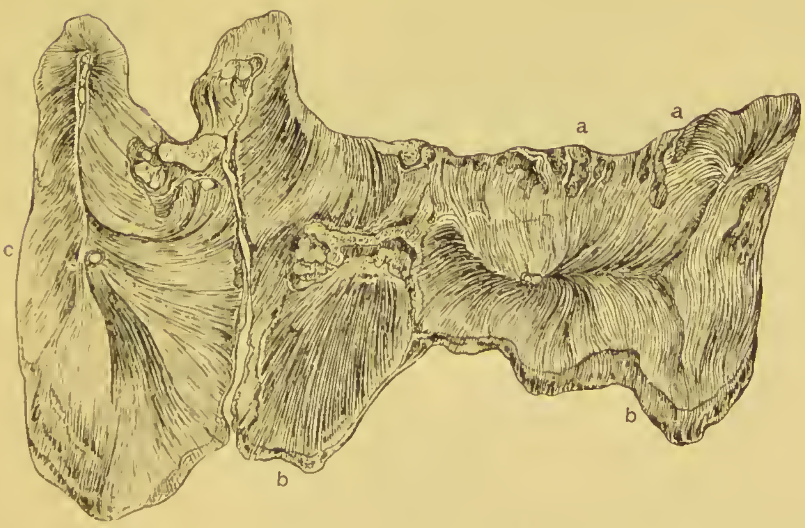
I. Odontoma, Tumor of the Dentine.—Up to Virchow's time every tumor of the teeth was dubbed odontoma. Virchow confined this term to tumors of the dentine only, and we ought to adhere to this nomenclature. Dentine tumors may arise from either the crown or the root in the shape of sessile or pediculated, smooth or lobate, even thorny outgrowths. (See Fig. 274.) If sprung from the dentine of the crown, they are

FIG. 274.



ODONTOMA OF A LOWER MOLAR. (From Wedl.)

FIG. 275.

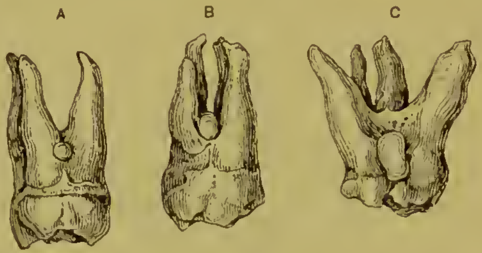


ODONTOMA. SECTION THROUGH THE THORNY PORTION OF FIG. 274. (From Wedl.)

a, a, folds of enamel; *b, b*, layers of enamel; *c*, central space, around which the dentinal canaliculi are arranged in a radiating manner. Magnified 10 diameters.

covered, as a rule, with an imperfect enamel, or with vestiges of formations arising from the root portion; such appear coated with a more or less perfect layer of cement. Their structure is sometimes similar to that of primary, sometimes to that of secondary, dentine, with irregularly-distributed groups of dentinal canaliculi. In rare cases the dentinal canaliculi are arranged radiatingly around spaces carrying blood-vessels, so-called vaso-dentine. (See Fig. 275.)

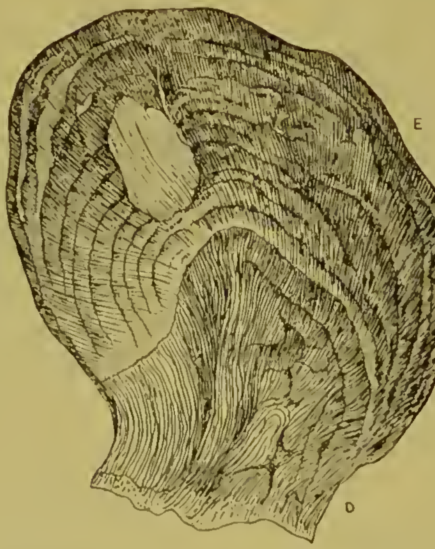
Fig. 276.



Teeth with Amelomata or Enamel-Drops. (From Wedl.)

A, ameloma on posterior surface of a left upper molar; *B*, a right upper molar with four roots, holding an ameloma between the internal roots; *C*, a left upper molar with four roots, holding an ameloma between the two posterior roots.

Fig. 277.

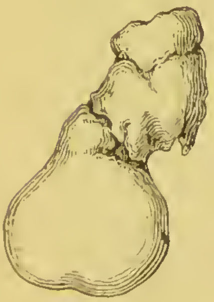


Ameloma or Enamel-Drop. (From Wedl.)

E, stratified enamel, deeply pigmented, especially toward the outer surface; *D*, dentinal cone, with irregularly-distributed dentinal canaliculi and interglobular spaces. Magnified 50 diameters.

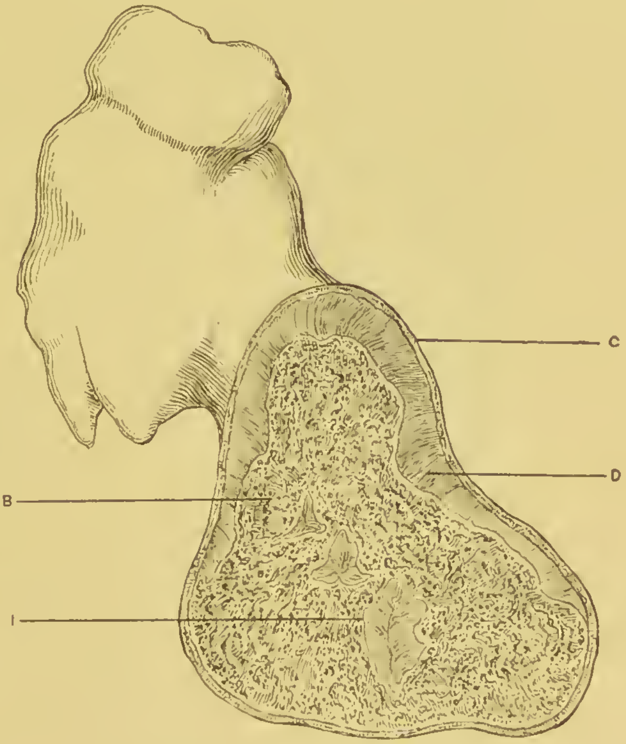
II. Ameloma, Tumor of Enamel.—Formations of this description are found in rare instances in the shape of white, smooth nodules, either globular or oblong, varying from the size of a pin's head to that of a small pea. They are invariably found at the beginning of the bifurcation of the roots near the neck, and are often connected with the enamel of the neck by means of a narrow ridge. (See Fig. 276.) In malformed or dwarfed teeth they are often found in numbers protruding from the ill-developed crowns. Their structure is that of normal enamel. At their base, which, as a rule, is broad, is seen a peg of normal dentine penetrating the center of the enamel-drop to a varying distance. (See Fig. 277.)

FIG. 278.



OSTEOMA OF NECK AND ROOT OF A MOLAR. (From Salter.)

FIG. 279.



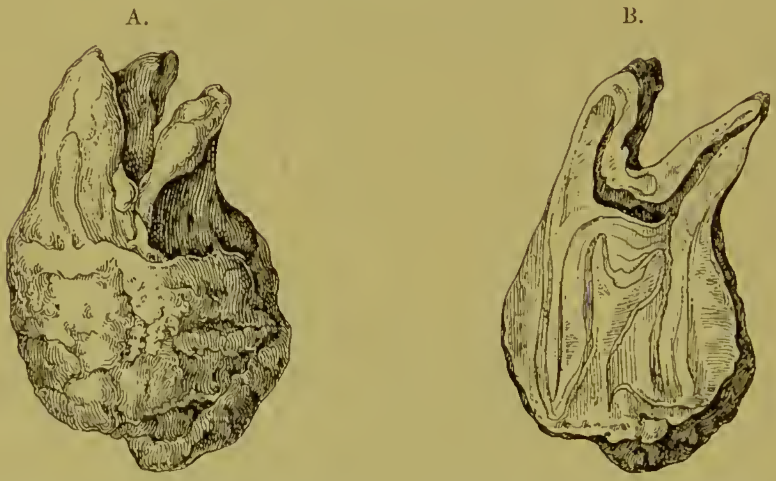
OSTEOMA OF NECK AND ROOT OF A MOLAR. VERTICAL SECTION. (From Salter.)

C, layer of cementum; *D*, layer of dentine; *B*, bone-tissue, the main mass of the tumor; *I*, islands of dentine. Magnified 3 diameters.

III. Osteoma, Bony Tumor of the Roots.—A tumor arising from the cementum of the roots is termed exostosis if circumscribed, and hyperostosis if diffuse. Such formations are probably the outcome of a long-continued irritation of the cementum. (See Chapter XXX.) In rare instances tumors of considerable size are found upon the roots, composed either of cancellous or compact bone-tissue with islands of dentinal tissue interspersed. For such tumors Salter proposed the rather awkward term "*hernia.*" (See Fig. 278.) Sometimes, instead of regular bone-tissue, we meet with globular masses, the so-called osteoid tissue. Cancellous bone is traversed by numerous blood-vessels; compact or osteoid tissue is scantily supplied with them. In Salter's case small islands of dentine were found in the middle of the newly-formed bone-tissue. (See Fig. 279.)

IV. Gigantic Growth, or Teratoma of Teeth.—This term may be applied to extremely rare specimens of an enormous outgrowth of the teeth, especially of their crowns, in which all three hard tissues of the tooth are involved. They may also be termed "teratoid," on account of their complicated structure. The best-studied example of such an enormous growth is that of C. Wedl, of the illustrations of which a copy is herewith shown. (See Fig. 280, *A* and *B.*)

FIG. 280.



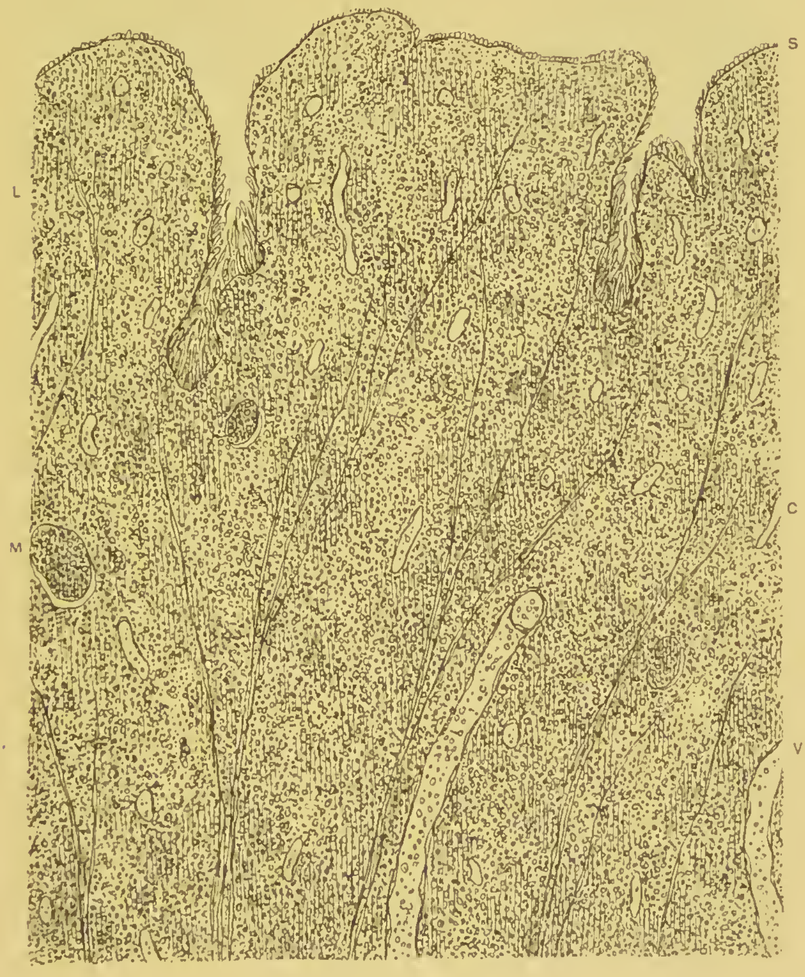
GIGANTIC GROWTH OF A RIGHT UPPER MOLAR. NATURAL SIZE. (From Wedl.)

GIGANTIC GROWTH OF A RIGHT UPPER MOLAR. SECTION THROUGH THE INNER AND BETWEEN THE TWO OUTER ROOTS. NATURAL SIZE. (From Wedl.)

V. Myeloma of the Pulp.—This form of malignant tumor was first described by C. Wedl. Another example is included in my own collection. Unfortunately, in neither of these instances is anything known concerning the history of the pulps affected.

In both cases the tumor proved under the microscope to be a so-called "round-celled sarcoma," or as I would prefer to term them, "lympho-myeloma." In both instances the tumors had grown in largely-decayed cavities of molars, much resembling the appearance of a granuloma or proud flesh of the pulp.

Fig. 281.

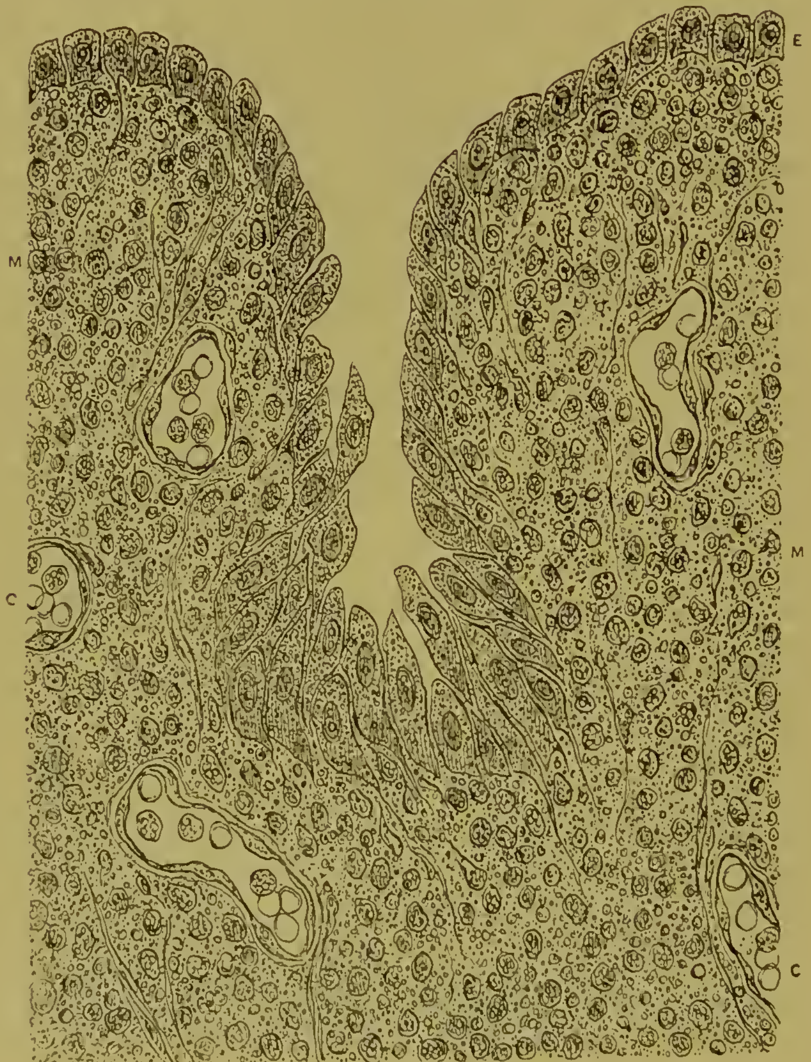


Lympho-Myeloma of Pulp.

S, surface made up of blunt papillary elevations, covered with a single layer of epithelia; *L*, tissue of lympho-myeloma; *M*, multinuclear protoplasmic body; *C*, capillary; *V*, vein. Magnified 50 diameters.

With low powers of the microscope the surface appears slightly lobated, in contradistinction to granuloma, which is distinctly papillary at its surface. (See Fig. 281.) In granuloma the blood-vessels are abundant; in myeloma scanty. The surface in the case examined was found to be covered with partly stratified epithelium, the same as in the case of granuloma described in the chapter on "Morbid Anatomy of Pulpitis," page 403.

Fig. 282.



Lympho-Myeloma of Pulp.

E, columnar epithelia at the surface; *M*, *M*, tissue of lympho-myeloma, with scanty spindles; *C*, *C*, capillary blood-vessels. Magnified 500 diameters.

With higher powers of the microscope there is a pronounced difference between granuloma and myeloma. (See Fig. 282.) In the former we see myxomatous tissue with a distinct quantity of basis-substance, especially in the deeper portions of the growth. In myeloma only vestiges of fibrous connective tissue can be seen, but no myxomatous basis-substance. The protoplasmic bodies are, in some places, crowded together to such a degree that they flatten one another. The proportion of living matter is much greater in the tissue of myeloma than in that of granuloma.

As to the origin of the covering epithelia, the chapter above referred to considers the two possibilities at some length.

CHAPTER XLVI.

CYSTS IN THE ORAL CAVITY.

From a histological point of view, only those tumors with liquid or semi-solid contents in which the connective-tissue sac is lined on its inner surface by epithelia can properly be called cysts. The best opportunity for studying genuine cysts is afforded by the skin, where the so-called sebaceous "wens" are of frequent occurrence. We know that every one of these cysts has an adenomatous preliminary stage.

In a certain portion of the acinous sebaceous glands new formations occur, with an augmentation of the epithelial structures, after which the gland becomes dilated, and fills with either a fatty, cream-like sebaceous mass, or a jelly-like liquid resembling honey, or with a serous liquid rich in albumin. The sebaceous mass which primarily filled the cyst becomes transformed by secondary changes into the semi-liquid or liquid material.

About the jaws we occasionally meet with epithelial growths originating from the remnants of the external epithelium, and the epithelial cord of the former enamel-organ, to which Magitot was the first to draw attention. These remnants consist of flat epithelia, arranged in concentric, onion-like nests, which may give rise to epithelial tumors even after the eruption of the permanent teeth. Cases have been observed in which such tumors formed on the internal surface of the cheek, of hard consistence, ulcerating on their surface, but entirely painless. Upon removal, a number of epithelial pearls were found imbedded in newly-formed connective tissue. (See Fig. 283.) Under the microscope these pearls can only be interpreted as remnants of the external epithelium or of the epithelial cord of the enamel-organ, which have been carried away from their original site into the mucous membrane of the cheek.

Such epithelial formations unquestionably may give rise to cysts, which, obviously, will be lined by epithelia and develop without symptoms of inflammation, though a cyst of this type may become inflamed and may even suppurate.

Quite different is the source of cystic tumors around the apices of the teeth, which, clinically as well as microscopically, demonstrate their origin from an inflammatory process; primarily, an accumulation of pus in a so-called alveolar abscess. The cavity is filled with a serous liquid, occasionally slightly turbid from remnants of pus. From what I have stated, the term cyst is not properly applied to instances where we find no epithelial lining, but we may resort to this term if we call them inflammatory cysts.

For convenience' sake I will divide the cysts occurring in the oral cavity into two classes,—viz:

I. Cysts arising from epithelial tissue; and

II. Inflammatory cysts. The latter develop from a so-called pyogenic membrane.

I. Epithelial Cysts.—The tumors of this class embrace all growths which develop either from glands or the remnants of a former enamel-organ, which are enumerated as follows:

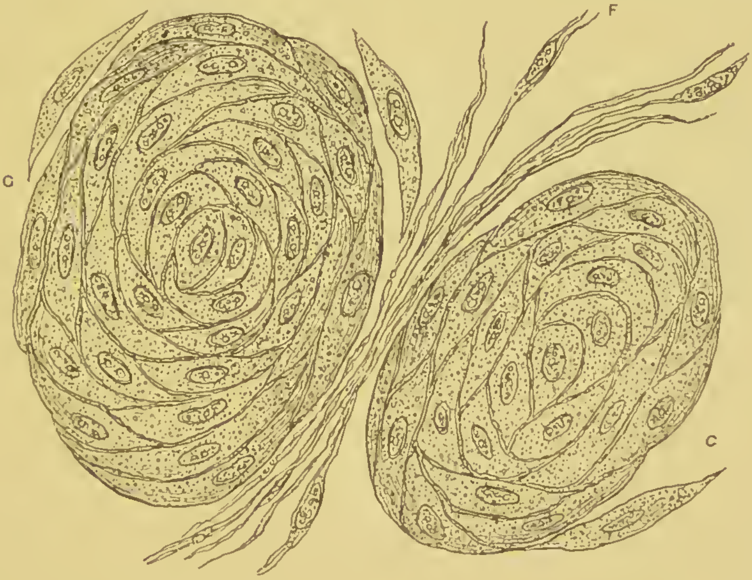
1, Ranula; 2, Mucoid Cysts; 3, Dental or Dentigerous Cysts; and 4, Alveolar Cysts.

1. *Ranula.*—This term has been applied to cystic formations occurring in the salivary glands on the floor of the oral cavity. Their size varies considerably; usually it is that of a hazel-nut, but sometimes they attain the bulk of a man's fist. Ranula always grows slowly, and when large it may become an impediment to speech, mastication, and respiration. It is sometimes translucent, in which case it exhibits a thin sac filled with liquid or semi-liquid contents. In other instances it is opaque and almost solid, which is due to a thick inclosing wall and semi-solid contents, consisting mainly of epidermal scales in fatty degeneration, and cholesterin crystals. The origin of ranula is as yet unsettled; the most commonly accepted theory

being that the cyst originates by a dilatation of the salivary gland. This theory, however, will not explain the appearance of ranulæ filled with epidermal scales. The latter variety probably originates from the so-called gill-ducts, which are present in the earliest stages of embryonal life.

2. *Mucoid Cysts.*—These tumors are of rare occurrence. They appear at almost any part of the oral mucous membrane where there are mucous glands, but usually on the inner surface of the cheeks and on the gums. They are translucent, bag-like formations, never larger than a pea in size, are superficially imbedded in the mucous membrane, and easily movable in all directions. They probably originate from adenomata of the mucous glands of the oral cavity. Their contents are usually of a liquid or a mucoid consistence.

Fig. 283.



Epithelial Globules from Scrapings of the Inner Cyst-Wall of the Right Cheek.

G, G, globules made up of concentrically-arranged epithelia; *F,* shreds of fibrous connective tissue. Magnified 500 diameters.

3. *Dental or Dentigerous Cysts.*—According to John Tomes,* the term "dentigerous cyst" is limited to cysts which arise in connection with developing teeth, or teeth which, though their development has been completed, are retained within the sub-

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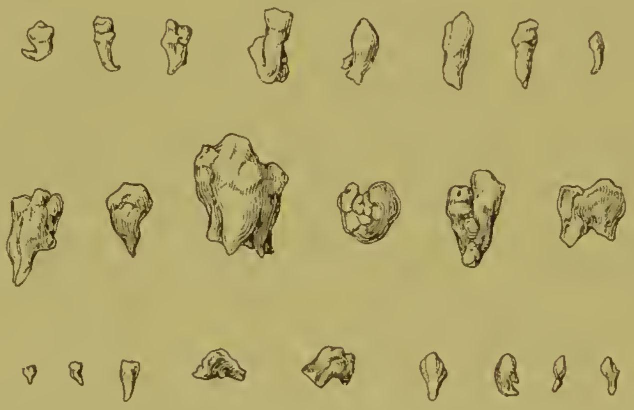
* "A System of Dental Surgery," 1873.

stance of the jaw. In the majority of cases they are connected with permanent teeth, and in some instances with supernumerary teeth. This author describes a remarkable cyst which contained twenty-eight supernumerary teeth. The patient stated that on the right side of the upper jaw the cuspid, bicuspids, and first molar had failed to make their appearance. At the age of twelve a hard, painless swelling appeared on that side of the jaw, which subsequently became inflamed and painful; at the same time pus oozed out in large quantities around the root of a temporary molar which had been retained. The twenty-eight teeth were dwarfed, and of very irregular form, one having no less than nine cusps. (See Fig. 284.)

Fig. 284.

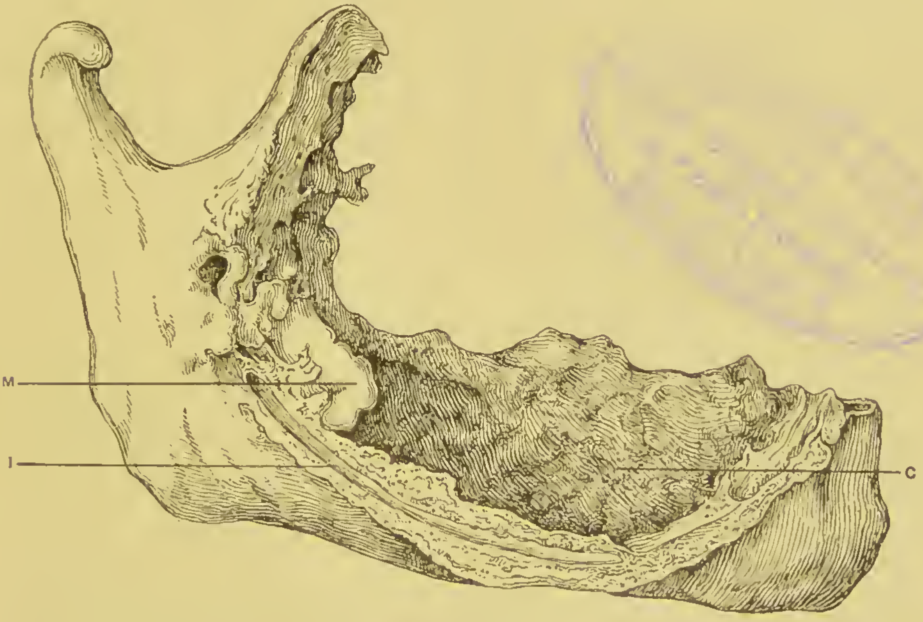


Dwarfed and Malformed Teeth out of a Dentigerous Cyst of the Right Side of the Upper Jaw. (From John and Charles S. Tomes.)

Another instance of a dentigerous cyst is described by John Tomes in a patient aged twenty-five, who presented with a large tumor in the front of the upper jaw, the surface of which was eroded by ulcers and profusely discharging offensive pus. Fifteen ill-developed, partly hyperplastic, and gigantic teeth were extracted, and probably a few more had been lost in the operation. The teeth absent from the mouth were the central and lateral incisors, the cuspids occupying their usual position.

J. Tomes states that cysts arising in connection with teeth retained in the jaw do not always contain a number of supernumerary teeth; often only a single tooth, commonly belonging to the permanent set, is found, though cases are recorded of cysts arising in connection with temporary teeth. In some cases bony walls develop around the cyst. Tumors of this type may attain to an enormous size, but they are very rare. Fig. 285 represents the bony wall of a dentigerous cyst, from a case in which Lisfranc had extirpated the affected half of the jaw.

Fig. 285.



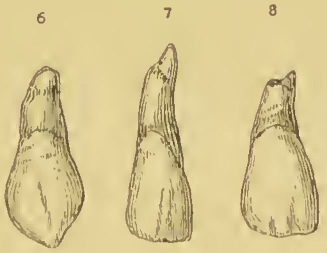
Dentigerous Cyst involving the Body and the Ramus of the Right Half of the Inferior Maxilla. (From Forgot.)

M, inverted third molar; *I*, inferior dental canal; *C*, internal wall of the cyst.

John and Charles S. Tomes remark that, had a correct diagnosis been made, a much milder procedure would have led to a cure.

Fig. 286 represents three teeth of the upper jaw found in a cyst by Dr. M. H. Cryer, of Philadelphia, and kindly offered to me for illustration.

Fig. 286.

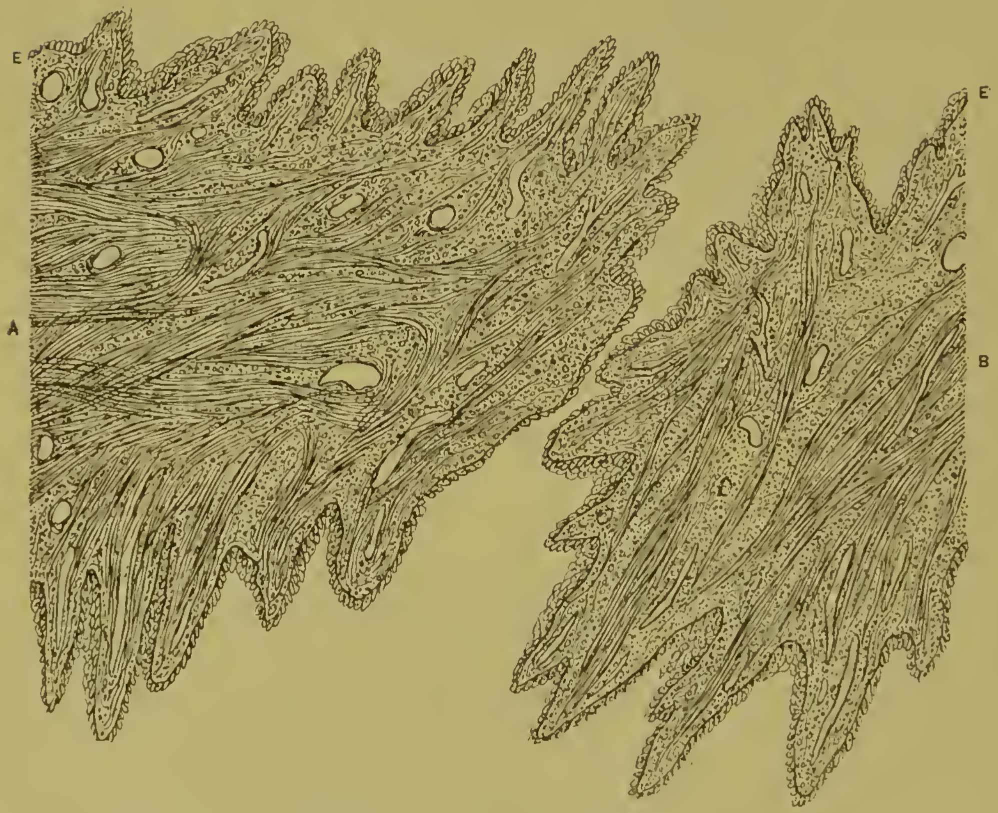


Right Upper Incisors and Cuspid found in a Cystic Cavity.

4. *Alveolar Cysts.*—In this group I propose to locate all cysts of undoubted epithelial origin, but not depending upon retained teeth. The case of which illustrations are attached was that of a man, about fifty years of age. The cyst, of the size

of a hazel-nut, was situated at the site of the left lower first molar, which was extracted some fifteen years ago. The wall of the cyst presented the appearance illustrated in Fig. 287. The inner surface was studded with papillæ covered by epithelia, the whole appearing lobulated. The lobules, two of which are seen in the figure, consist of bundles of fibrous connective tissue, freely supplied with capillary and venous blood-vessels, the connective tissue being, in many places, crowded with inflammatory corpuscles.

Fig. 287.



Papillary Vegetations at the Inner Surface of Cyst-Wall.

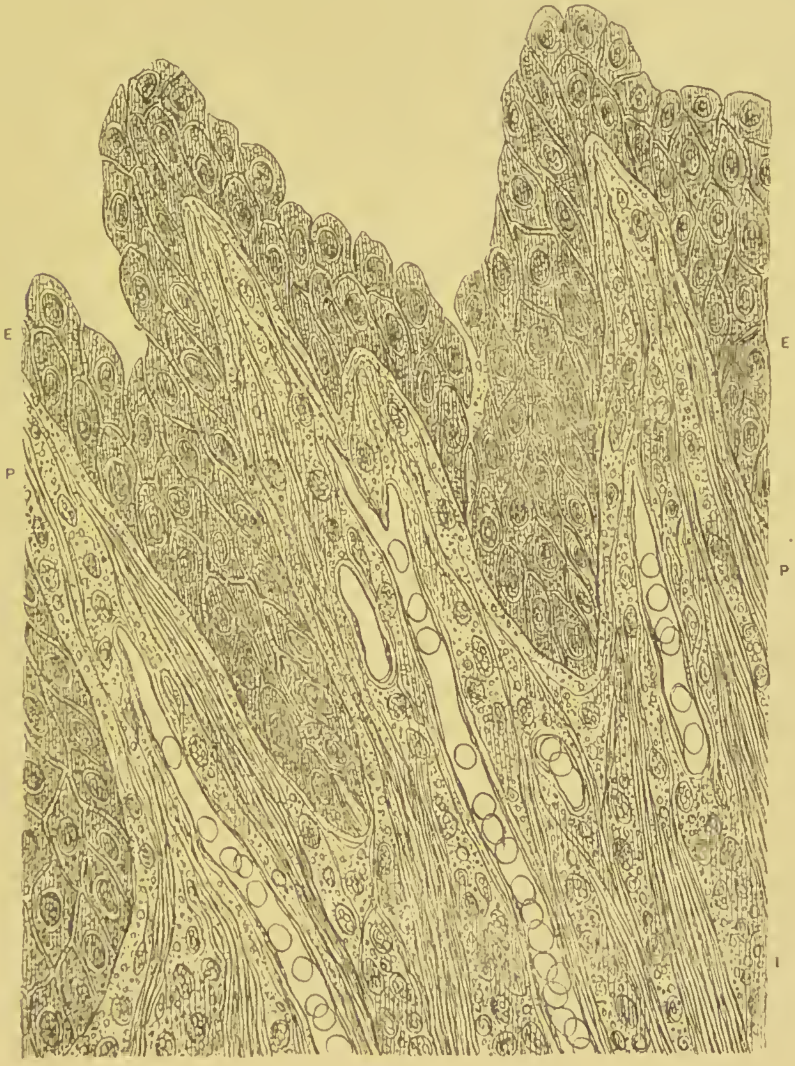
A, *B*, vegetations crowded with papillæ; *E*, *E*, stratified epithelium covering the papillæ. Magnified 50 diameters.

With higher power of the microscope, the epithelium covering the papillæ proved to be indistinctly stratified. (See Fig. 288.)

II. Inflammatory Cysts.—The origin of inflammatory cysts is, in the majority of cases, as follows:

The pulp of a tooth becomes devitalized, causing an alveolar abscess, whereby a portion of the adjacent cancellous bone-tissue of the socket is destroyed. The pus makes its way to the surface of the alveolar process, which is covered with remnants of the periosteum or only with mucous membrane. The suppuration comes to a standstill, and the abscess is what the surgeons usually call encysted. In turn, the pus-corpuscles either creep back into the lymphatics and are carried away, or they become hydropic and are destroyed. If mucous membrane is the only outer covering of the sac, it usually bulges into the oral cavity in the shape of a tense, elastic tumor, exhibiting

FIG. 288.



PAPILLARY VEGETATIONS AT THE INNER SURFACE OF CYST-WALL.

P, *P*, papillæ made up of fibrous connective tissue, with numerous capillary blood-vessels; *I*, inflammatory infiltration of fibrous connective tissue; *E*, *E*, stratified epithelium covering the papillæ. Magnified 500 diameters.

fluctuation, but lacking symptoms of inflammation. Should the wall of the sac hold remnants of periosteal tissue that have escaped destruction, it will give rise to a new formation of bone, which, in turn, may envelop the sac with an osseous wall. Since such a newly-formed bony wall is, as a rule, thin and imperfect, the tumor will remain elastic and compressible.

A noteworthy fact about these inflammatory cysts is that they occur only in persons of a poor constitution, in whom the inflammatory process advances but slowly. The pus in these instances is rather serous, containing but a limited number of pus-corpuscles that are easily liquefied.

The diagnosis of alveolar cysts is usually not difficult. Such cysts are met with more frequently in the upper than in the lower jaw, and they are mostly situated in the outer wall of the alveolar process. They are found more frequently upon the incisors and bicuspids than the molar teeth, and very seldom near the roots of the cuspids. When a cyst develops in the neighborhood of the antrum, it may lead to an incorrect diagnosis. In these instances the cyst may bulge into the antrum, pressing its floor upward, thus occupying almost the entire cavity. In such a case the cyst may be mistaken for empyema of the antrum, especially if the offending tooth or root has been removed some time previous. The wall separating the cyst from the antrum is usually left intact, and the communication between the antrum and the nasal cavity is cut off. Another important fact in the diagnosis of alveolar cysts is the absence of catarrhal inflammation in the nasal passage on the affected side, which, in an empyemic condition of the antrum, always is or has been present. We also have to take into consideration the size of the cyst. If this be large and occupying almost the whole of the antrum, the wall common to both the antrum and the cyst may become perforated, and a discharge of the contents of the cyst into the nasal cavity be the result. When the outer bony wall of a cyst is thin, the tumor will be compressible, with the sensation of crepitation. The growth of a cyst usually is slow. In the first stages, and so long as no acute inflammation occurs, the patient experiences no pain, nor inconvenience. When, however, the sac begins to assume greater dimensions, the patient may be troubled by headaches as well as a disturbance of the eyesight, more or less confined to the affected side. Pressure with the finger produces no pain, unless the tumor has become large and tense. In the advanced stages slight percussion upon the tooth from which the cyst originated is painless, and the tooth itself is usually firm in its socket.

The prognosis of cystic tumors is generally favorable, except in those rare instances when a perforation of the wall of the antrum has taken place. The complete removal of the sac or a portion of it will usually prevent recurrence.

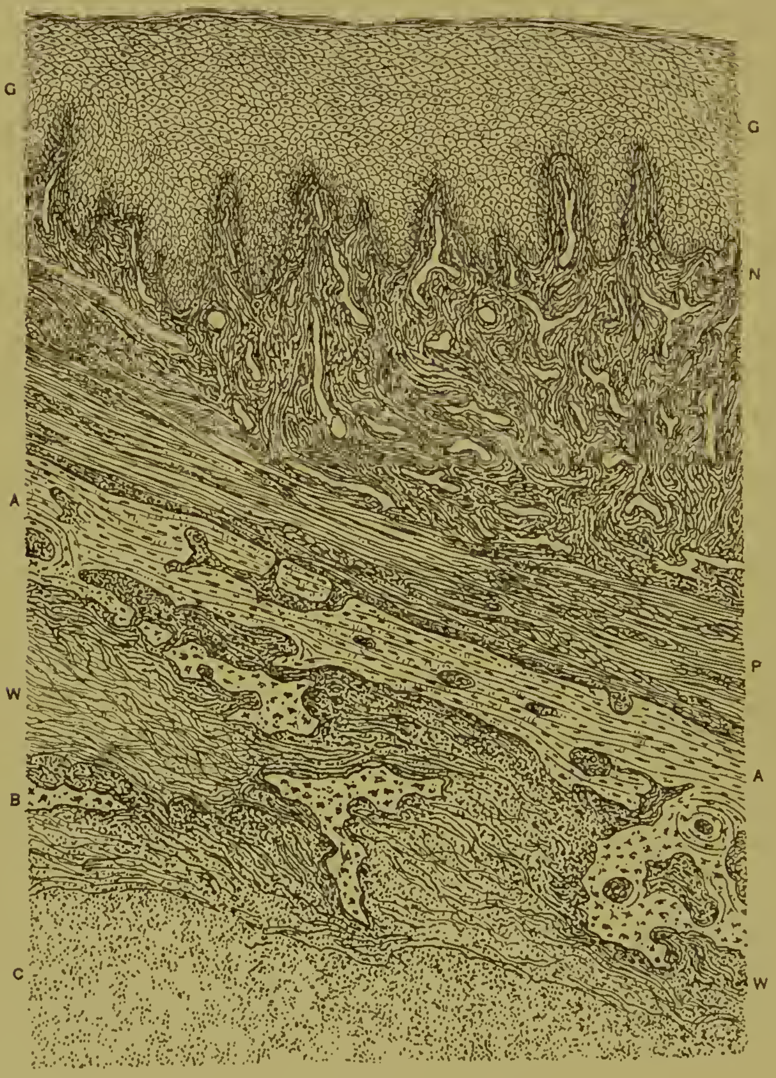
When a cyst develops around the root of an incisor tooth without the root being absorbed by the inflammatory process, the removal of the tooth is not absolutely necessary. If the root-canal of an otherwise normal tooth with but one root be thoroughly disinfected and filled, it may be left in the mouth without fear of recurrence of the cyst.

The microscopical study of specimens from the wall of the cyst is of considerable interest, since it offers an opportunity to trace both the destructive and formative actions of the inflammatory process.

Transverse sections through the wall of the cyst exhibit the following. (See Fig. 289.)

The outermost layer is established by the unbroken gum, partly normal and partly changed by chronic ulitis. The papillæ in the latter places are irregular in size and shape, the border toward the epithelial covering being rather indistinct. The connective-tissue layer of the gum exhibits dilated blood-vessels. Next follows the periosteum of the socket, composed of coarse interlacing bundles of fibrous connective tissue, with numerous inflammatory nests. The most pronounced inflammatory changes are observed along the border of the cancellous bone-tissue. The bony wall of the alveolus is considerably reduced in bulk, being pierced by numerous bay-like excavations filled with medullary or myxomatous tissue. Where the outer lamellated layer of the socket is still preserved, the cancellous bone-tissue has been reduced by the inflammatory process to scanty and irregular spiculæ of bone-tissue. These are in connection with the outer wall of the socket, or apparently isolated by a newly-formed myxo-fibrous connective tissue which forms the wall of the cyst. This tissue again holds spiculæ of newly-formed bone. The specimens in many places are crowded with red blood-corpuscles, so-called hæmorrhagic infarctions, which, judging from the fresh appearance of the red blood-corpuscles, must have been produced by extravasation during the removal of the wall of the cyst. The contents of the cyst are made up of coagulated albumin and red blood-corpuscles. No vestige of previous pus-corpuscles can be detected.

Fig. 289.



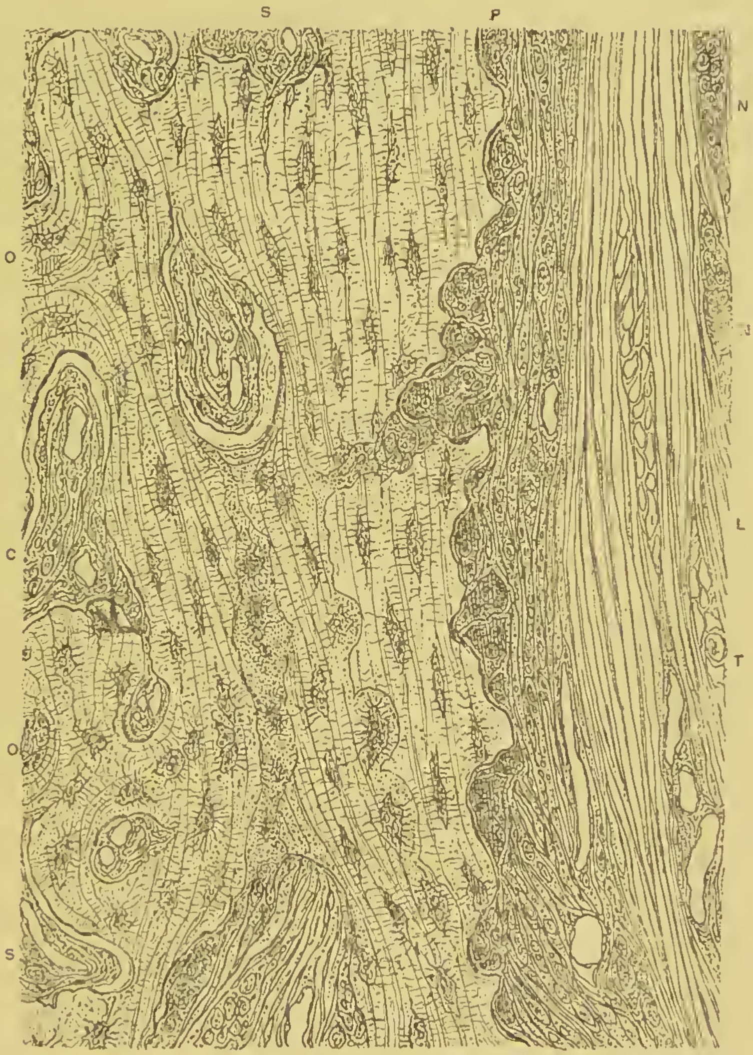
Wall of an Inflammatory Cyst in Transverse Section.

G, *G*, stratified epithelium of gum; *N*, partly normal, partly inflamed papillæ of gum; *P*, periosteum with inflammatory nests; *A*, *A*, wall of alveolus, much reduced by osteitis; *W*, *W*, myxo-fibrous tissue-wall of cyst, partly in hæmorrhagic infarctus; *B*, newly-formed spicula of bone-tissue; *C*, contents of cyst. Magnified 25 diameters.

The layers adjacent to the tissue of the gum are the periosteum and the bone, both considerably altered by the inflammation, as represented in Fig. 290.

The fibrous tissue of the periosteum holds numerous inflammatory nests. They consist of granular protoplasmic bodies which had not developed into new fibrous connective tissue. At its surface the bone-tissue is marked by numerous excavations varying in depth, and filled with multinuclear protoplasmic bodies, or myeloplaxes. The bone is honeycombed with medullary spaces that are filled partly with myxo-fibrous tissue, resembling that of the cyst-wall proper.

FIG. 290.



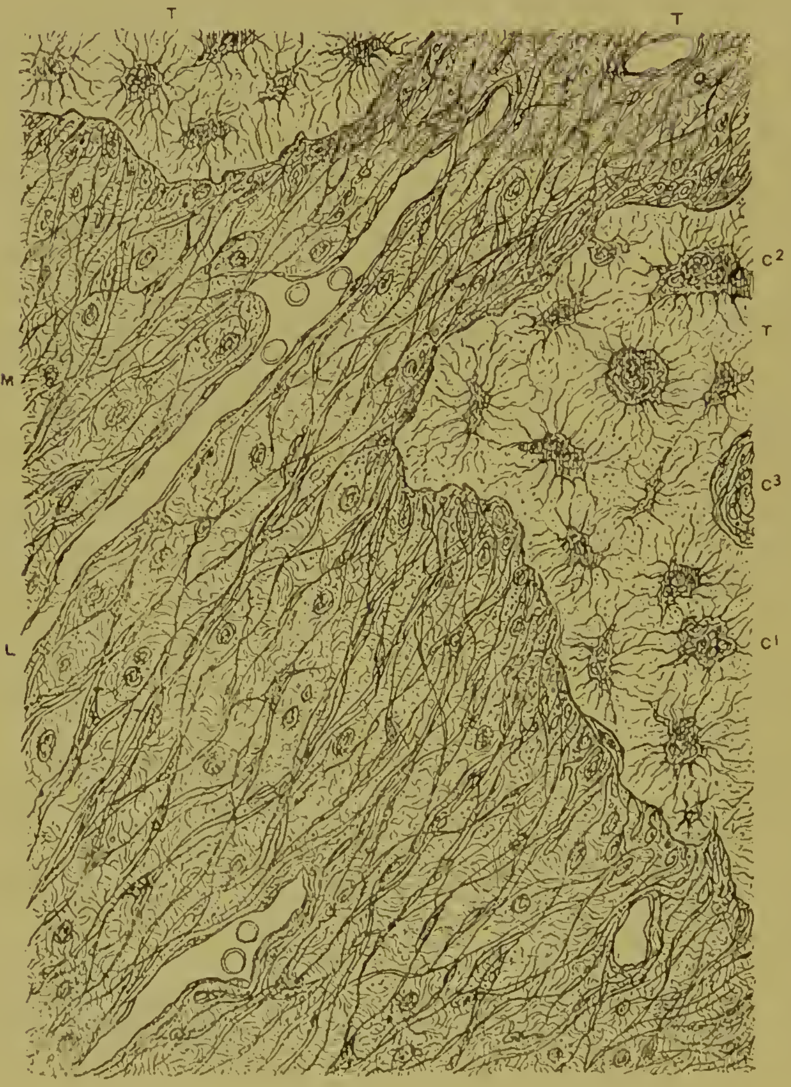
PERIOSTITIS AND OSTEITIS.

L, longitudinal bundles of periosteum; *T*, transverse bundles of periosteum; *N*, *N*, inflammatory nests; *M*, myxo-fibrous connective tissue; *P*, multinuclear protoplasmic bodies filling the bays of bone-tissue; *O*, *O*, osteitis, enlarged and confluent bone-corpuscles; *S*, *S*, medullary spaces of inflamed bone-tissue, filled with myxo-fibrous tissue; *C*, calcified rim around medullary space. Magnified 200 diameters.

The changes in the inflamed bone-tissue are still more conspicuous if examined with higher powers. (See Fig. 291.)

Here we observe bone-corpuscles of greatly varying sizes. The smallest are scarcely as large as normal ones, so that we may consider them as former offshoots, so-called canaliculi, which have been enlarged by the liquefaction of the decalcified glue-yielding basis-substance. Other bone-corpuscles are not materially altered in size, but different from normal ones by a

Fig. 291.



Osteitis and Myxo-Fibrous Tissue of Cyst-Wall.

T. T, trabeculæ of bone, much reduced by osteitis; *C*¹, bone-corpuscles, slightly enlarged; *C*², bone-corpuscles, much enlarged; *C*³, bone-corpuscles, transformed into a medullary space; *M*, myxo-fibrous connective tissue; *T* (right upper), capillary blood-vessel in transverse section; *L*, capillary blood-vessel in longitudinal section. Magnified 500 diameters.

coarse granulation of their protoplasm. Many, however, have become augmented in size to such a degree that they have reached the diameter of Haversian canals. All these enlarged bone-corpuscles hold, besides coarse granules, a varying number of homogeneous lumps, some reaching the size of nuclei. By a confluence of such enlarged bone-corpuscles we observe the origin of medullary spaces in the bone, independent of previous medullary spaces or Haversian canals.

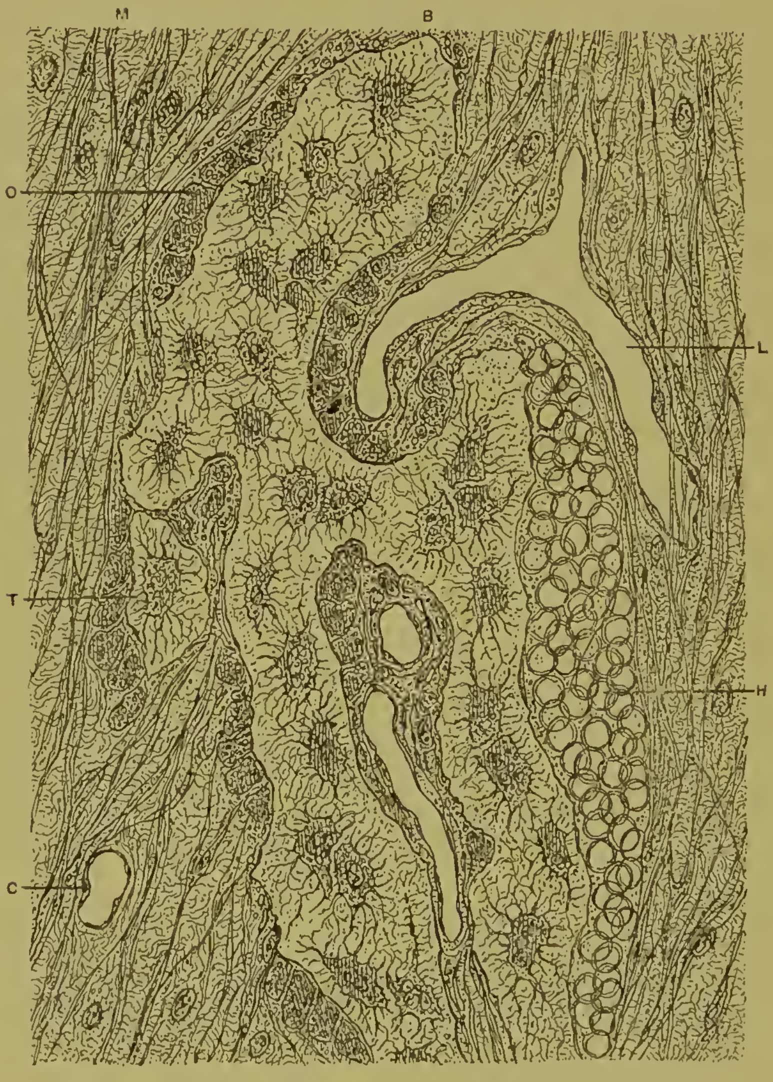
The cyst-wall proper is altogether made up of a myxomatous and myxo-fibrous connective tissue, only scantily supplied with capillary blood-vessels. Thirty years ago this tissue was not recognized by R. Virchow, who claimed that the layer bordering upon a pus-cavity was unfinished pus, which he termed "pus crudum." That this view is not correct is proved not only by my specimens, but also by the study of L. Heitzmann on "Abscesses in the Skin" (*Arch. f. Dermatol.*, 1892).

The myxomatous tissue is composed of branching tracts of a delicate fibrous reticulum, at the points of intersection of which we see so-called branching stellate protoplasmic bodies. The fields of basis-substance are likewise of a delicate reticular structure, and contain small homogeneous or coarsely-granular bodies, about the size of lymph-corpuscles. It can scarcely be doubted that this newly-formed tissue, the like of which is never observed in normal bone or periosteum, is the outcome of an inflammatory or medullary tissue, into which both the bone and the periosteum have been transformed by the process of inflammation.

In the myxo-fibrous cyst-wall we frequently meet with depositions of lime-salts, as well as newly-formed spiculæ of bone-tissue. (See Fig. 292.)

The trabeculæ of this newly-formed bone in the wall of the cyst are but few and small in size. We notice in their vicinity deposits of lime-salts without any indication of bony new formation. The only feature indicative of future bone is the presence of calcified medullary corpuscles, arisen from the myxomatous tissue. The next step toward the formation of bone is the appearance of territories. By the coalescence of a number of territories a spicula of bone-tissue will be formed, which invariably shows at its periphery more or less perfect rows of medullary corpuscles, the so-called "osteoblasts." A second characteristic feature of the newly-formed bone-tissue is the large size and great irregularity in the shape of the bone-corpuscles, the offshoots of which are unusually well pronounced. The third feature is the absence of lamellæ. Such bony spiculæ are found imbedded in fibrous or myxo-fibrous connective tissue, but never in a purely myxomatous one.

Fig. 292.



Newly-Formed Spicula of Bone-Tissue in Cyst-Wall.

B, spicula of bone, traversed by medullary spaces; *O*, row of osteoblasts; *T*, territory of bone-tissue; *M*, myxo-fibrous tissue of cyst-wall; *L*, capillary blood-vessel in longitudinal section; *C*, capillary blood-vessel in transverse section; *H*, hæmorrhagic infarctus. Magnified 500 diameters.

CHAPTER XLVII.

TUMORS OF THE JAWS.*

I. Myxoma.—This variety of tumor is not rare on the gums around the teeth. The specimen under observation is the size of a robin's egg, with a nodulated surface, originally of a blood-red color, of rather soft consistence, and grown upon the gum of the lower jaw, left side between the second bicuspid and first molar. It had recurred at every pregnancy, this being the third, in the mouth of a lady aged about twenty-six years. Tumors had been removed from the same locality four different times, when the patient was a girl from twelve to fourteen years of age.

With low powers of the microscope the raspberry or papillary appearance was well marked upon the surface, as represented in Fig. 293. The surface is coated with a single row of columnar epithelium, without distinct boundary toward the subjacent connective tissue, the lowest portions of columnar epithelia and the bodies wedged in between them blending with the adjacent layers of medullary tissue. The so-called structureless layer can be made out in but few places. The main mass of the growth consists of an extremely delicate net-work of fibrous connective tissue with interspersed nuclei mainly at the points of intersection. The meshes of this net-work contain as a rule only one medullary corpuscle; but near the surface the corpuscles are present in large numbers, to such an extent that the reticulum is rendered invisible. The corpuscles are comparatively small and nearly compact near the periphery, while they are granular and markedly larger in the deeper portions. The outermost portions of the tumor, owing to the abundance of medullary corpuscles, have the character of a myeloma; but the gradual appearance of a myxomatous basis-substance in the deeper portions proves that the tissue is myxomatous, and the clusters of the medullary corpuscles merely signify a rapid growth at the surface.

A striking feature of this growth is the large number of wide capillary blood-vessels, which run mainly in a vertical direction to the surface, and therefore appear in transverse sections where

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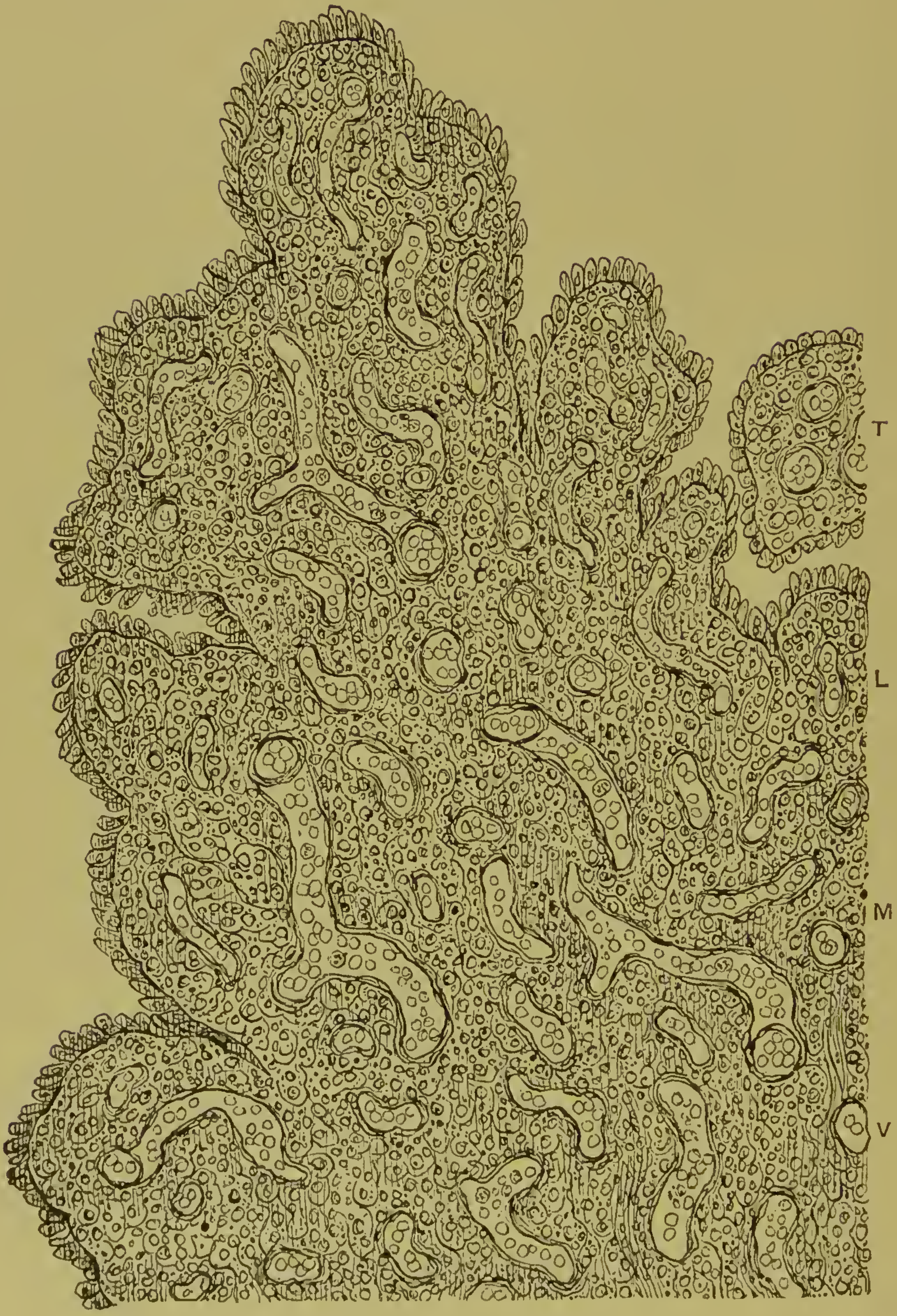
* The greater portion of this chapter has been taken from an article, "Contributions to the Knowledge of Tumors of the Jaws," by Carl Heitzmann and Frank Abbott. *Dental Cosmos*, 1888.

Fig. 293.



Myxoma or Granuloma of the Gum of the Lower Jaw.

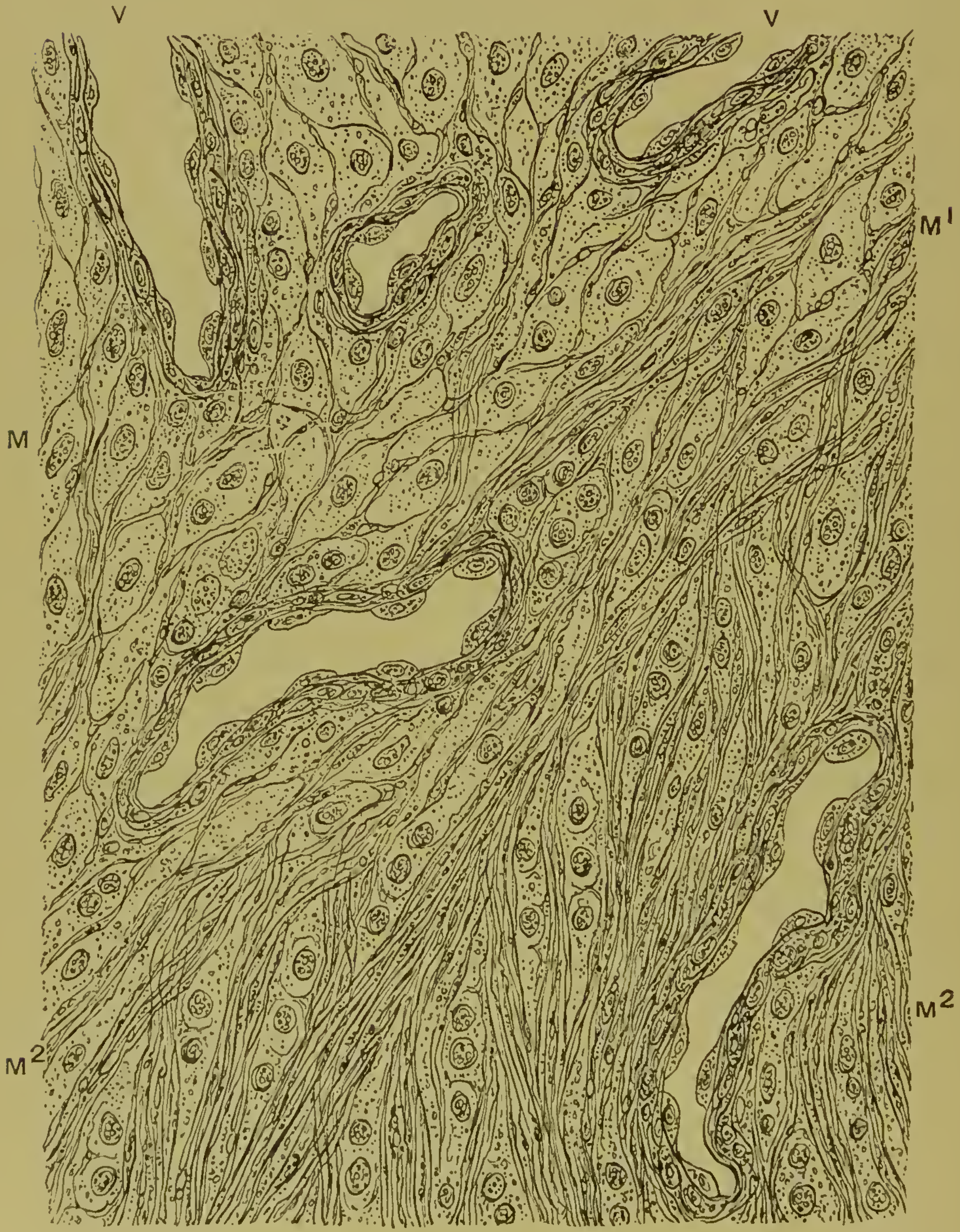
L, longitudinal; *T*, transverse section of the papillæ on the surface; *M*, myxomatous tissue; *V*, blood-vessels traversing the myxomatous tissue. Magnified 200 diameters.

the papillæ are cut transversely. The arrangement of the capillaries in a tassel-like manner seems to account for the papillary or nodular architecture of the surface. The so-called proud-flesh or granulation-tissue of suppurating wounds has the same structure as the tumor under consideration, and some authors speak of a granuloma corresponding to the structure of a myxoma, but being a product of an inflammatory process. In the deeper portions of the tumor delicate bundles of fibrous connective tissue are visible, and most of the vessels are accompanied by tracts of such tissue, by which an adventitial coat is produced, even around the capillaries, which is not visible in normal tissue. In the deepest portions the fibrous connective tissue is rather abundant, the medullary corpuscles being at the same time scanty, and the blood-vessels bearing the character of veins.

II. **Myxo-Fibroma.**—This variety of benign tumors is likewise known as occurring frequently, taking issue both from the gums and the periosteum. Its consistence is harder than that of a pure myxoma, and softer than that of a pure fibroma. (See Fig. 294.)

The illustration is taken from the deepest portions of the myxoma above described. It consists of interlacing bundles ot a delicate fibrous connective tissue, exhibiting therefore an indistinct reticular arrangement. The meshes between the bundles are filled with a finely-granular basis-substance, in which medullary corpuscles are stored up in varying numbers. The blood-vessels are comparatively scanty, consisting of capillaries and veins, all of which are surrounded by a distinct layer of fibrous connective tissue. The endothelia of the capillaries are unusually large and bulging toward the channel. In some places the capillary appears to be surrounded by two or more endothelial layers, which add considerably to the thickness of the vascular wall. The specimen affords a good opportunity for the study of the manner in which, first, myxomatous arises from medullary, and fibrous from myxomatous tissue, a process which, as is well known, is of frequent occurrence in the history of development of normal fibrous connective tissue. At first the tissue is apparently nothing but an aggregation of indifferent or medullary corpuscles, the tissue nature of which is determined only by the fact that all the corpuscles are united with one another by means of delicate threads. The corpuscles themselves are originally small homogeneous lumps, of a high degree of refraction. Soon afterward a number of such indifferent corpuscles assume a granular appearance, and between them an extremely delicate reticulum appears as the first trace of a reticular structure. At this stage of development, which we often see

Fig. 294.



Myxo-Fibroma of the Gum of the Lower Jaw.

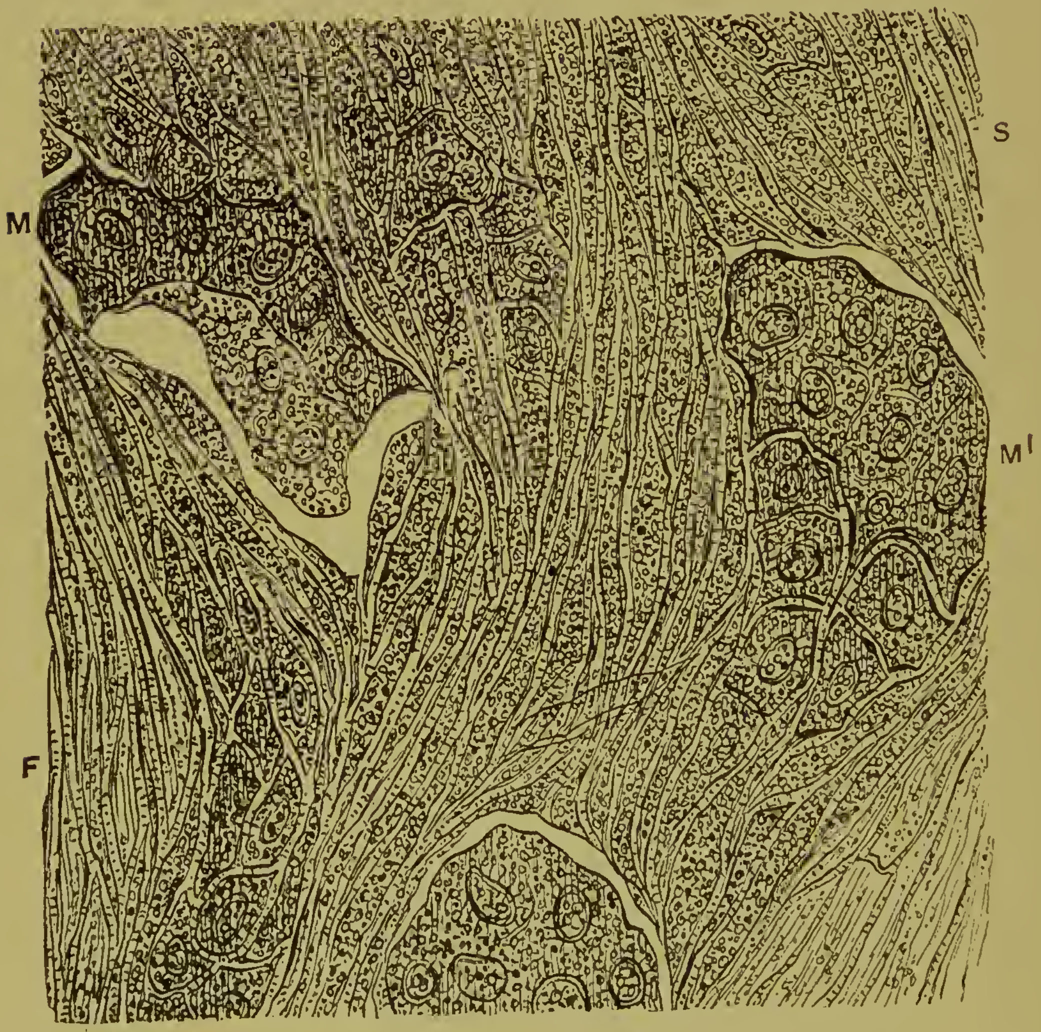
M, myxomatous tissue, composed of delicate fibrous bundles; *M*^{1}, the bundles coarser still, exhibiting the reticular arrangement; *M*^{2}, the fibrous bundles, broad, inclosing fields of a myxomatous basis-substance; *V*, *V*, large capillary blood-vessels. Magnified 500 diameters.

in inflamed tissue, some authors have spoken of an adenoid or lymph-tissue, by which designation is meant the appearance of a delicate myxomatous reticulum. In the next stage many of the medullary corpuscles are transformed into a myxomatous basis-substance, which with lower powers of the microscope looks either homogeneous or finely granular. Fields of such transformed medullary corpuscles have either one or several corpuscles unchanged, and are bordered by a delicate fibrous reticulum at the points of intersection, at which small oblong or globular corpuscles are seen. In this stage of development the tissue is called purely myxomatous.

If, by a further splitting up of the medullary corpuscles into delicate spindles, the fibrous reticulum is augmented, and the fields of myxomatous basis-substance narrowed, we have a transition from myxoma into myxo-fibroma, and this transition is the more marked the broader the bundles of fibrous connective tissue. All these stages, to be sure, cannot be traced in direct transition from one into another, but we conclude, from observing the successive portions of the same tumor, being medullary at the periphery and fibrous at its base, that the former are the youngest and least developed, and the latter the oldest and most advanced.

III. Fibroma.—Solid and dense tumors of a very slow growth, starting from the periosteum of the jaw-bones, are of rather frequent occurrence and well known to surgeons. The name given to them was "epulis," which means a tumor growing upon the gum. Obviously this is a misnomer, since we know that tumors of this description take issue as a rule from the periosteum, and invade the gum in a rather secondary way. One of the striking features of such benign tumors is the presence of protoplasmic masses with a varying number of nuclei, the so-called giant-cells of previous pathologists. They are present in greatly varying numbers, mainly in that portion of the tumor nearest the periosteum, often being arranged in groups, and lacking altogether in the peripheral portions of the growth. (See Fig. 295.) When such bodies are visible they are, as a rule, surrounded by embryonal tissue, and it is easy to observe their origin from a varying number of medullary corpuscles. The latter coalesce, thereby losing their individual boundary lines, and produce a uniformly granular mass of protoplasm, in which we recognize either scattered nuclei or coarser granules, so-called nucleoli. Around the corpuscle, which is often of irregular shape, sending offshoots into the neighboring medullary tissue, the adjacent medullary corpuscles produce a kind of capsule, between which and the multinuclear bodies a gap is not infrequently seen,—caused, as it were, by the shrinkage of the "giant-cell." It is known that bodies of this description are often met with in the normal medullary tissue of forming and growing bone. We often find

FIG. 295.



BASE OF FIBROMA WITH MULTINUCLEAR BODIES, SO-CALLED GIANT-CELLS.

S, spindle-shaped medullary corpuscles; *F*, fibrous basis-substance having originated from spindle-shaped medullary corpuscles; *M*, multinuclear body retracted from the surrounding medullary tissue; M^1, multinuclear body in connection with large medullary or endothelial elements. Magnified 1200 diameters.

them in those bay-like excavations that appear in the cementum and dentine of temporary teeth during the process of their absorption. The prevailing idea as to their significance is that they grow by coalescence of leucocytes or medullary corpuscles, from without into the cement or dentinal tissue, liquefying on their way these tissues, and breaking them up. Hence their name, "osteoclasts," or "bone-breakers."

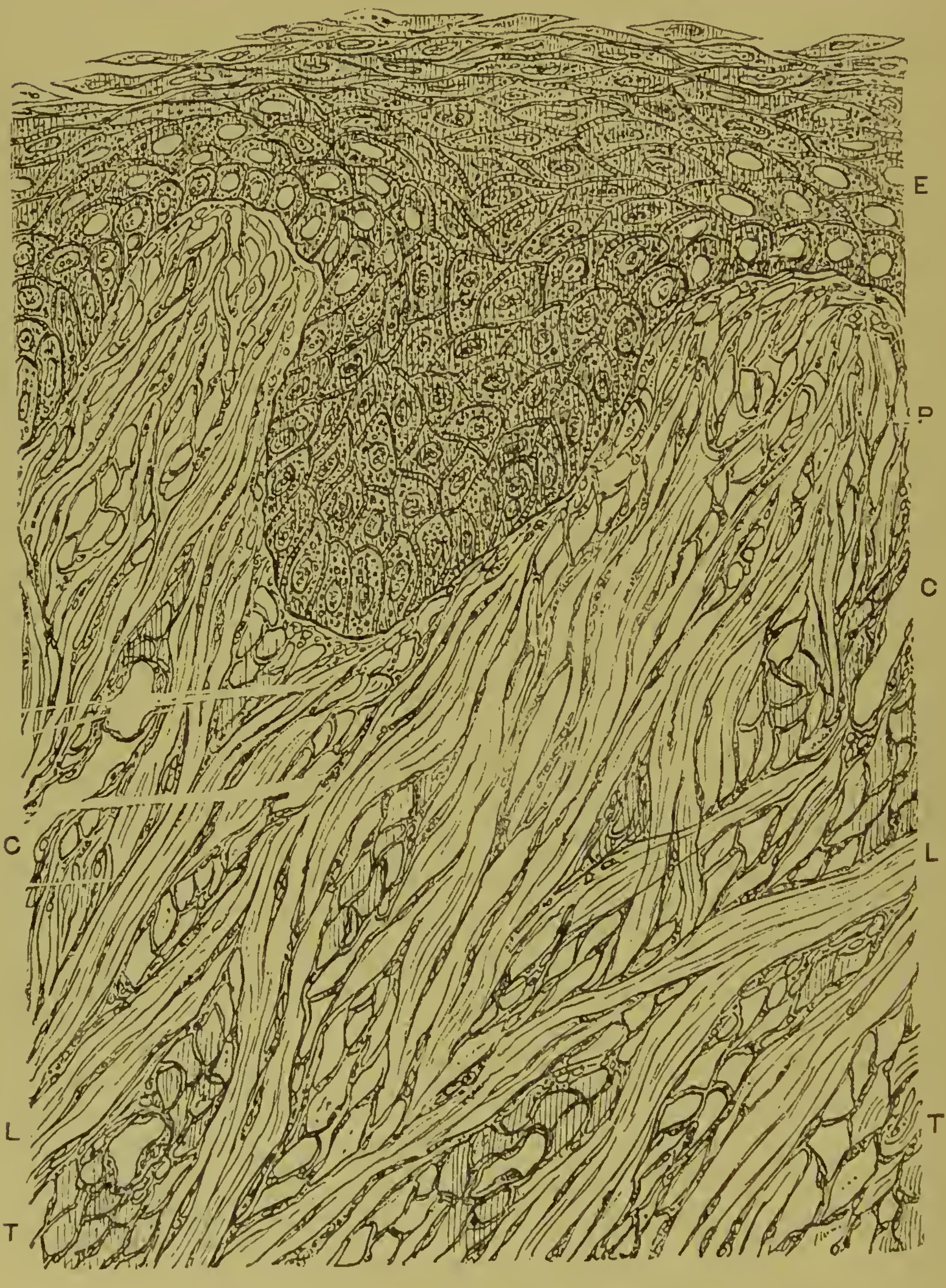
We must decidedly disagree with such views, since we have seen multinuclear protoplasmic bodies arising from the living matter of cementum and dentine itself, after the dissolution of the lime-salts and the liquefaction of the basis-substance. Furthermore, we have often seen such bodies in the medulla, preceding the formation of bone-tissue. Since the territories of formed bone-tissue often are transformed into such multinuclear bodies, the idea becomes admissible that they can appear previous to development of the osseous territory; and to this view corresponds their presence in the periosteal portion of fibrous tumors. We admit, however, that this view does not account for the presence of so-called giant-cells in every instance, since, as we will show later on, they accompany blood-vessels, and are known to exist in inflammatory products,—for instance, in tubercles.

The tumor before us appeared on the alveolar process of the upper jaw in the shape of a sessile nodule, the size of half a hickory-nut, in a youth about twenty years of age. (See Fig. 296.)

The surface of the tumor looked comparatively smooth to the naked eye, but microscopical specimens show remnants of the papillæ of the gum, rather shallow and blunt, and some distance apart. The outer coating is made up of stratified epithelium, whose layers are noticeably diminished, probably owing to the pressure of the growth from within. The first row of columnar epithelia is well marked only in the valleys between the remnants of the papillæ, while on their summits the first row is composed of short columnar, or rather cuboidal epithelia. In these places both the epithelia of the first and the neighboring epithelia of the adjacent layers exhibit central vacuoles, or plasmatic spaces, from which the nuclei have dropped out.

The bundles of the fibrous connective tissue are of considerable breadth throughout the mass of the tumor, but their breadth increases from the outer to the deeper portion. The protoplasmic tracts are well marked between the bundles, both in longitudinal and transverse sections. The bundles are freely decussating or interlacing, by which an extremely dense trestle-

FIG. 296.



FIBROMA OF THE ALVEOLAR PROCESS OF THE UPPER JAW.

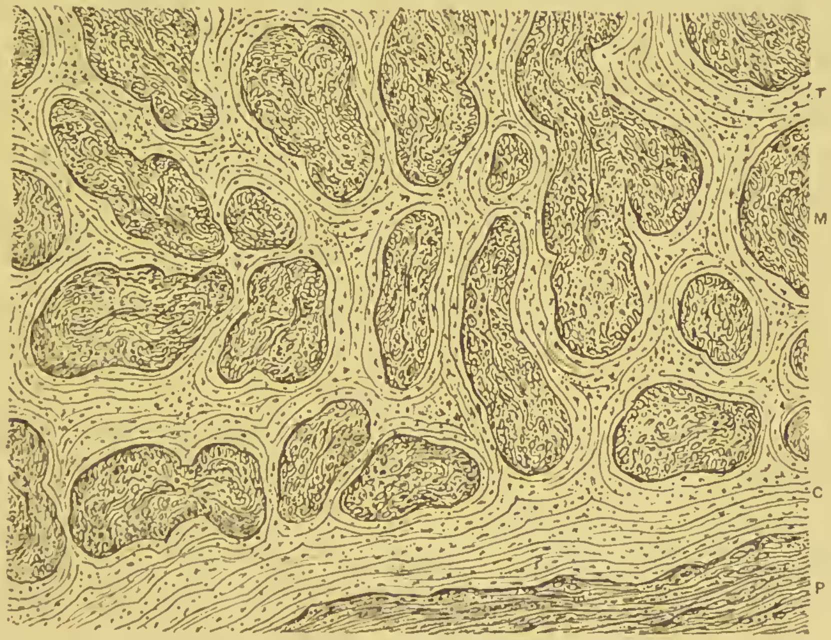
E, stratified epithelium of the gum; *P*, blunt papillæ of the gum; *L*, *L*, longitudinal, *T*, *T*, transverse sections of bundles of fibrous connective tissue; *C*, *C*, capillary blood-vessels. Magnified 500 diameters.

work, similar to that of the derma of the skin, is produced. The vessels are scanty throughout the tissue, consisting mainly of capillaries.

At the outer portion of the tumor, between the bundles, small nests of medullary tissue are discernible. The deepest portions, on the contrary, are made up largely of medullary tissue, composed of globular and spindle-shaped corpuscles, with a goodly number of interspersed multinuclear bodies. The latter feature does not mean a transformation from the benign fibroma into a malignant myeloma, but the juvenile condition of the connective tissue, and a somewhat accelerated growth from beneath. This is proved from the fact that the tumor did not return after removal.

IV. Osteoma.—The great majority of bony tumors of the jaws are of the cancellous or spongy variety. Compact or cortical osteoma is a great rarity. The specimen illustrated in Fig. 297 was taken from a tumor the size of a small hazel-nut, which grew in the median line of the hard palate near the soft palate. A similar though much smaller tumor had been removed two

FIG. 297.



CANCELLOUS OSTEOMA OF HARD PALATE.

P, periosteum ; *C*, thin cortical layer ; *T*, trabeculæ of cancellous bone ; *M*, medullary space. Magnified 100 diameters.

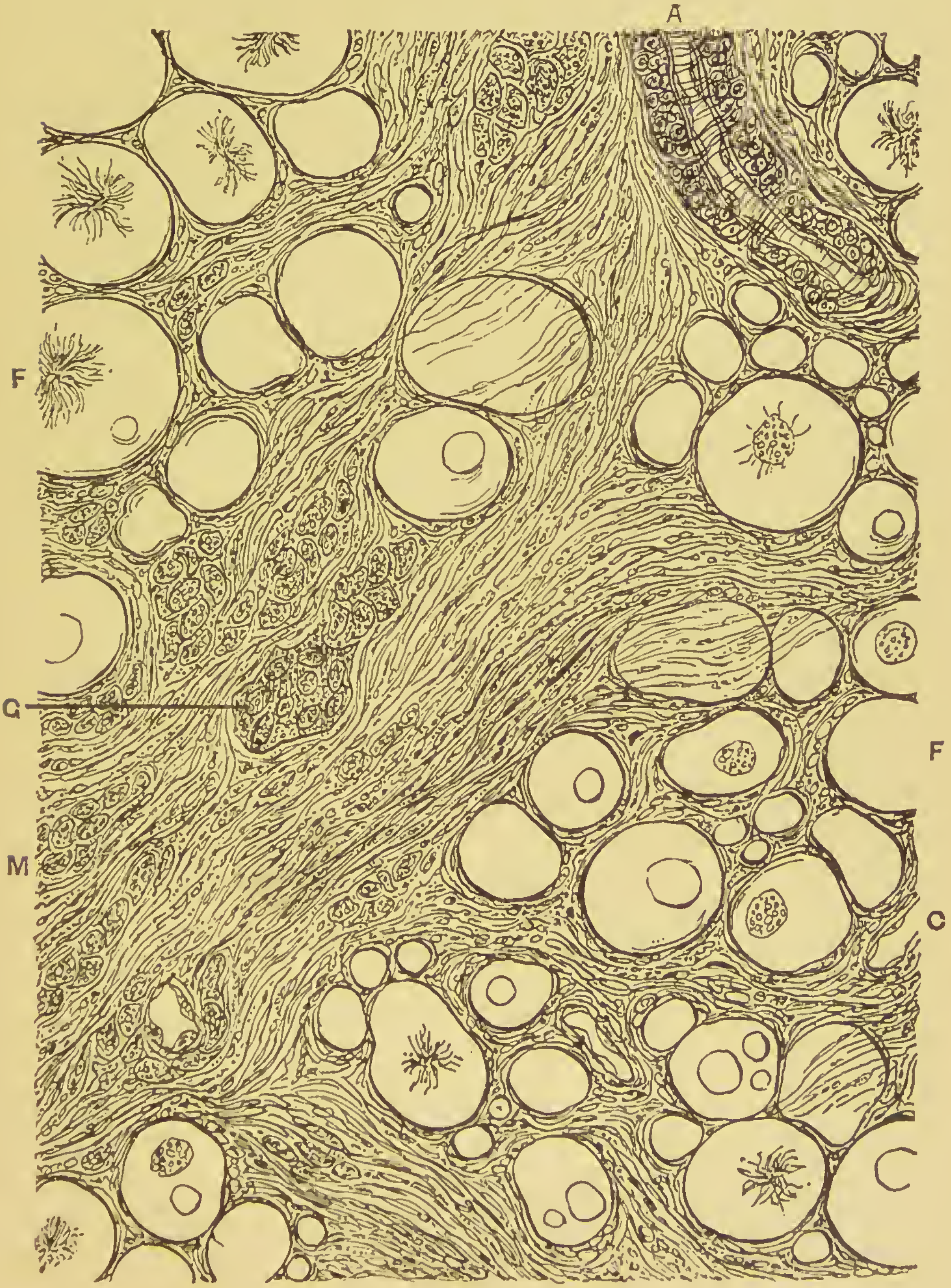
years previously from the hard palate of the same patient, a man about forty years of age. The structure is strictly that of epiphyseal bone, composed of osseous trabeculæ inclosing medullary spaces and surrounded by a thin cortex.

V. Chondroma.—A number of tumors of cartilaginous nature have been observed upon the jaws (Rokitansky, Pitha, Wedl, etc.), all with a hyaline basis-substance in which protoplasmic bodies, so-called cartilage-corpuscles, were imbedded. No specimen of this type of tumor being at our disposal, its illustration is omitted.

VI. Lipo-Fibroma.—In our collection there is no tumor from the jaws made up of fat to such an extent as to warrant a diagnosis of lipoma. One specimen, however, removed from the lower jaw, the size of a cherry, shows a combination of fibrous connective with fat-tissue, and thus gives the variety expressed in the title. The fat-globules are greatly varying in size, and either arranged in groups or scattered singly in the connective tissue; arteries are accompanied by rows of such globules. Most of the latter contain vacuoles and peculiar star-shaped formations in their centers, which very probably are not crystals of margaric acid, as some previous observers have believed, but remnants of protoplasm which are known to exist in each fat-globule. (See Fig. 298.)

The connective tissue is of two kinds,—viz, partly broad and heavy bundles, and partly narrow spindles, not arranged in distinct bundles. These two varieties are intermixed without any regularity throughout the entire tumor, the latter being especially conspicuous in the neighborhood of the fat-tissue, where it produces a thin layer, carrying blood-vessels between the fat-globules, or surrounds groups of them. The connective tissue contains a number of clusters of medullary corpuscles, which, if flattened out and rendered polyhedral by mutual pressure, present the aspect of endothelia, and if coalesced into one mass represent multinuclear bodies or giant-cells. The history of development of fat-tissue demonstrates that each globule of a larger size arises from a number of medullary corpuscles, which are transformed chemically into fat, whereas the central portions remain unchanged protoplasm, with branching offshoots; much on the plan of territories with central cartilage or bone-corpuscles. Small fat-globules may be the products of transformation of single medullary corpuscles, or a limited number thereof. It has long been known that, in animals in which emaciation is induced rapidly by starvation, each fat-globule breaks up into a number of medullary corpus-

FIG. 298.



LIPO-FIBROMA OF LOWER JAW.

F, *F*, fat-globules; *M*, clusters of medullary corpuscles; *G*, multinuclear body or giant-cell; *A*, artery. Magnified 400 diameters.

cles,—viz, into the embryonal material which originally gave rise to the formation of a globule. If we recall the fact that each fat-globule is surrounded by a thin connective-tissue capsule, invariably supplied with a nucleus, fat at once appears as a variety of myxomatous tissue, the difference being only a chemical alteration of the protoplasm into carbohydrates or fat, instead of a mucoid basis-substance.

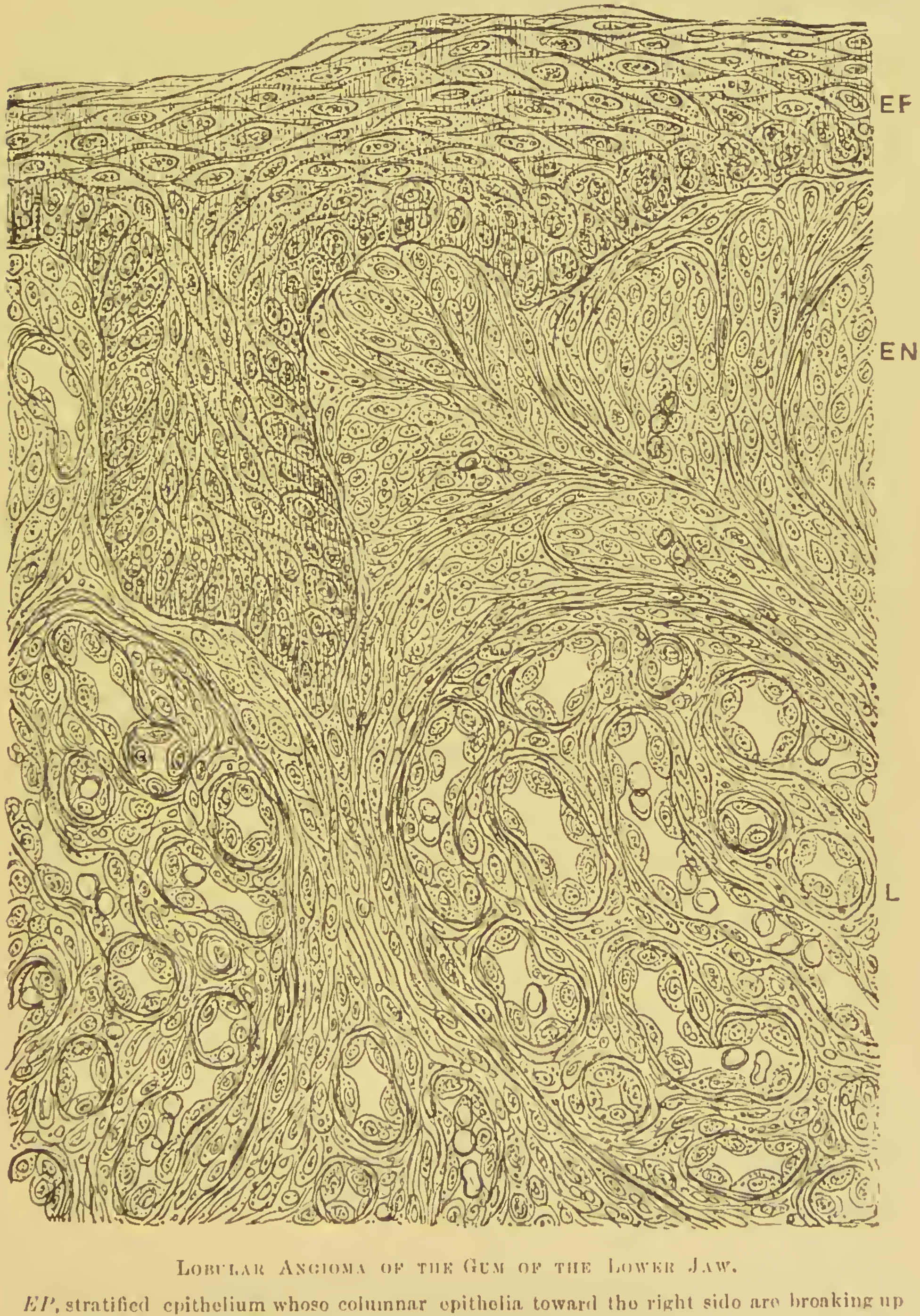
From this point of view, the clusters of medullary or endothelial corpuscles would simply represent a pre-stage of future fat-globules or remnants of previous ones. Since multinuclear bodies or giant-cells are known to result from a coalescence of medullary or endothelial corpuscles, there is good reason to assume that these bodies likewise would represent, eventually, either a previous or a past stage of fat-globules. A fat-globule, according to our view, is a globular territory with a central protoplasmic body, growing in exactly the same manner as a territory of myxomatous, cartilaginous, or osseous tissue: the nucleus always belonging to the capsule around the globule. and not to the globule itself. A territory of any of the tissues named will break up, in the process of physiological or reduction in pathological conditions, into clusters of medullary corpuscles, or into multinuclear protoplasmic bodies.

VII. Angioma.—A boy, eleven years of age, presented himself with a tumor the size of a small hickory-nut on the gum of the lower jaw, occupying the region of the right lateral incisor and cuspid, having its rise in a somewhat narrow pedicle between the teeth. The surface was nearly smooth, slightly lobulated: its consistence rather soft, and easily compressible; its color dark red. Pressure with the finger rendered the tumor pale. considerably diminishing its bulk at the same time, but as soon as the pressure ceased the previous size and color returned. Three months previously a similar tumor had been removed from the same place, but it almost immediately commenced to grow again with alarming rapidity, causing a slightly uneasy feeling, but no pain.

Vertical sections through the body of the tumor revealed the fact that its interior was composed mainly of blood-vessels, but that the outer and inner portions differed in structure. The former exhibited the features of a lobular, the latter of a cavernous, angioma.

a. Lobular Angioma.—The surface of the vascular or erectile tumor is covered with a stratified epithelium, being normal in its breadth at the borders, and much thinned in the middle portions of the tumor. In the former places there are visible

FIG. 299.



LOBULAR ANGIOMA OF THE GUM OF THE LOWER JAW.

EP, stratified epithelium whose columnar epithelia toward the right side are breaking up into medullary corpuscles; *EN*, endothelial layer traversed by radiating tracts of a delicate fibrous connective tissue; *C*, capillary blood-vessels in the endothelial layer; *L*, *L*, lobules composed mainly of capillary blood-vessels. Magnified 500 diameters.

numerous rather shallow papillæ, a certain number of which are united into a group by deep epithelial valleys. In the central portions only a limited number of layers of cuboidal epithelia are discernible, the deepest layer being absent, and replaced by medullary corpuscles to such an extent that no boundary line could be made out between the epithelium and the subjacent connective tissue. (See Fig. 299.)

The connective-tissue layer beneath the epithelium is made up of nucleated granular corpuscles, closely packed together,—so much so that they flatten each other into broad spindles. Bodies of this description are termed endothelia. A limited number of tumors of this variety have been described since Bizzozero, of Italy, drew attention to their occurrence, and dubbed them endothelioma. They are found mainly in connection with lipoma and angioma.

The endothelia appear to be arranged in clusters, between which delicate tracts of a fibrous connective tissue run in a somewhat radiating order, which tracts, if viewed with higher powers of the microscope, appear to be made up of narrow, partly-nucleated spindles. The tracts spread toward the periphery in a fan shape, and no clear distinction is possible here between the broad spindles of the endothelia and the narrow spindles of the tracts.

Some distance below the epithelia, or close beneath them, a large number of capillaries are seen cut in longitudinal, oblique, and transverse sections, which means that these blood-vessels are coiled up into a lobular shape. Between the lobules there are either tracts of endothelia mixed with fibrous connective tissue, or bundles of the latter alone, and these interstitial tracts bear capillaries of their own, independently of those within the lobules.

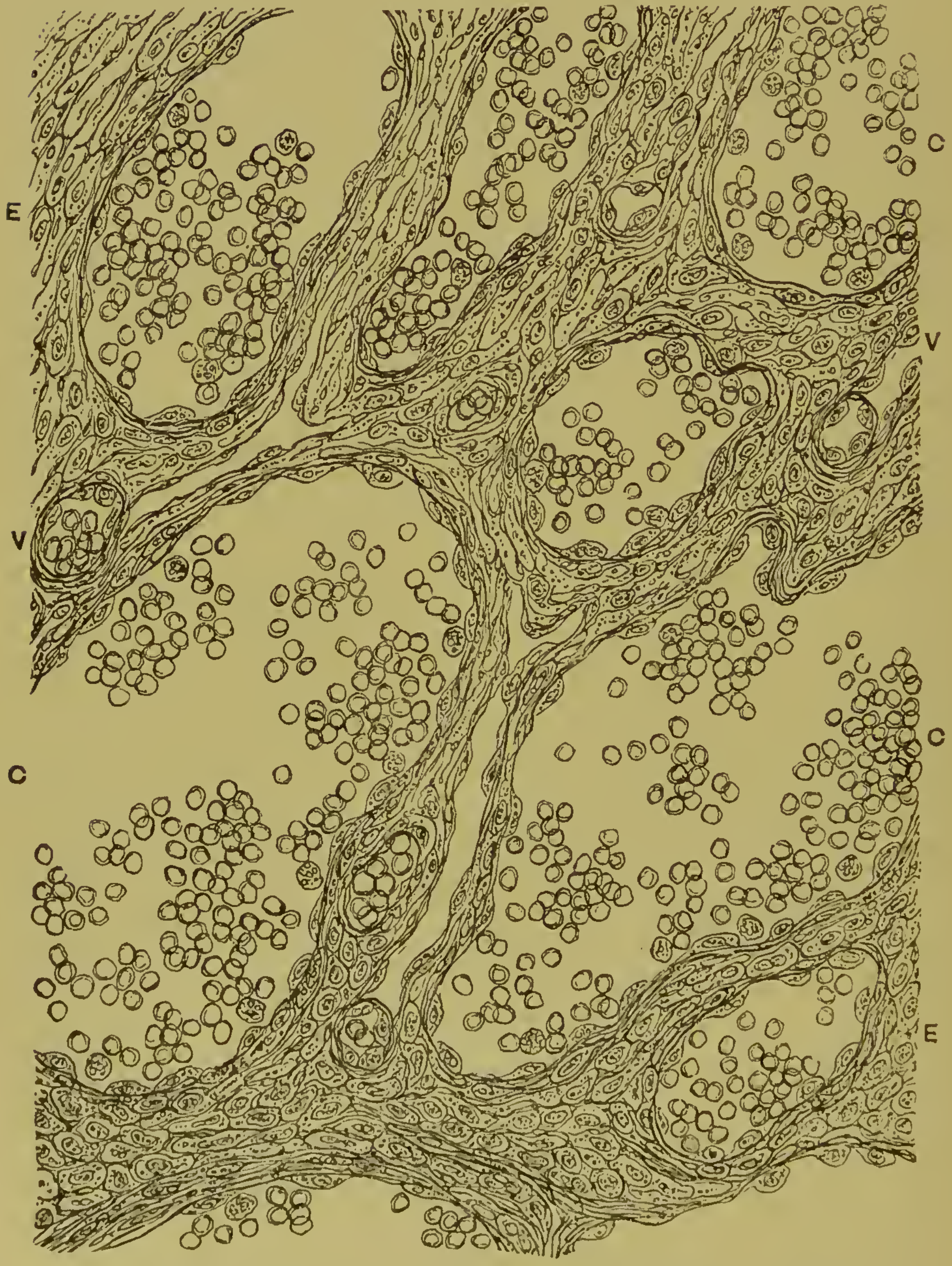
The most striking feature in the endothelial layers is the formation of red blood-corpuscles and blood-vessels. At first isolated lumps appear in the endothelia, characterized by a high degree of refraction, and yellow in color. They are smaller than red blood-corpuscles, and are known by the name of "hæmatoblasts." Increasing in size, they assume the appearance and structure of red blood-corpuscles. Clusters of hæmatoblasts, or fully-formed red blood-corpuscles, are surrounded by circular tracts of endothelia which, being hollowed out in part, lead to the formation of channels already filled with blood, whereas a number of endothelia of rather large size furnish the walls of the capillaries. Thus the formation of red blood-corpuscles precedes that of blood-vessels, as stated some forty-five years ago by the late Rokitansky, of Vienna. Thus it also becomes plain that the tissue termed endothelioma is, at least in many instances, a pre-stage of angioma. Obviously the newly-formed blood-vessels, though containing blood-corpuscles from the very issue, are closed tubes or saccules, which later, through a continued vacuolation of the endothelia, inosculate with already-formed blood-vessels; their tenants, the blood-corpuscles, entering into circulation.

b. Cavernous Angioma.—The lower portions of the tumor under consideration have a different structure, gradually blending with that of lobular angioma. Here we notice large cavities, at first lined by several layers of endothelia, and containing a varying number of red blood-corpuscles, until at last very large spaces make their appearance, filled with red blood-corpuscles; and thus the character of a cavernous angioma is established. (See Fig. 300.)

We observe, at first, tracts of endothelia accompanied by a delicate fibrous connective tissue, with irregular calibers, in which a liquefaction of a certain number has taken place, as indicated by their hydropic condition, to such an extent that only a delicate frame-work of previous endothelia is discernible. A certain number of endothelia have been transformed into red blood-corpuscles; another set furnishes colorless blood-corpuscles, or possibly these arise from the nuclei of previous endothelia. The process is known to histologists by the term of "vacuolation of the endothelia." The calibers at first are very irregular, being bounded by several layers of endothelia, and it sometimes occurs that tolerably well-formed calibers of the same vessel are connected with one another by narrow canals, owing to the presence of little changed endothelia. Blood-corpuscles may be seen in one part of the caliber, and are absent in another, so long as the vessels are not complete. The remaining endothelia are large, and supplied with oblong nuclei of considerable size.

Fully-formed cavities in connection with the physiological vessels are characterized by smaller endothelia, not surpassing in size those of normal veins. The trabeculæ inclosing the venous cavities are made up of fibrous connective tissue, carrying their own capillary blood-vessels. In many places, however, even the trabeculæ are made up of endothelia, and it is easy of demonstration that the endothelia are merely the medullary or embryonal stage of connective tissue, since we can trace

Fig. 300.



Cavernous Angioma from the Base of a Vascular Tumor of the Gum.

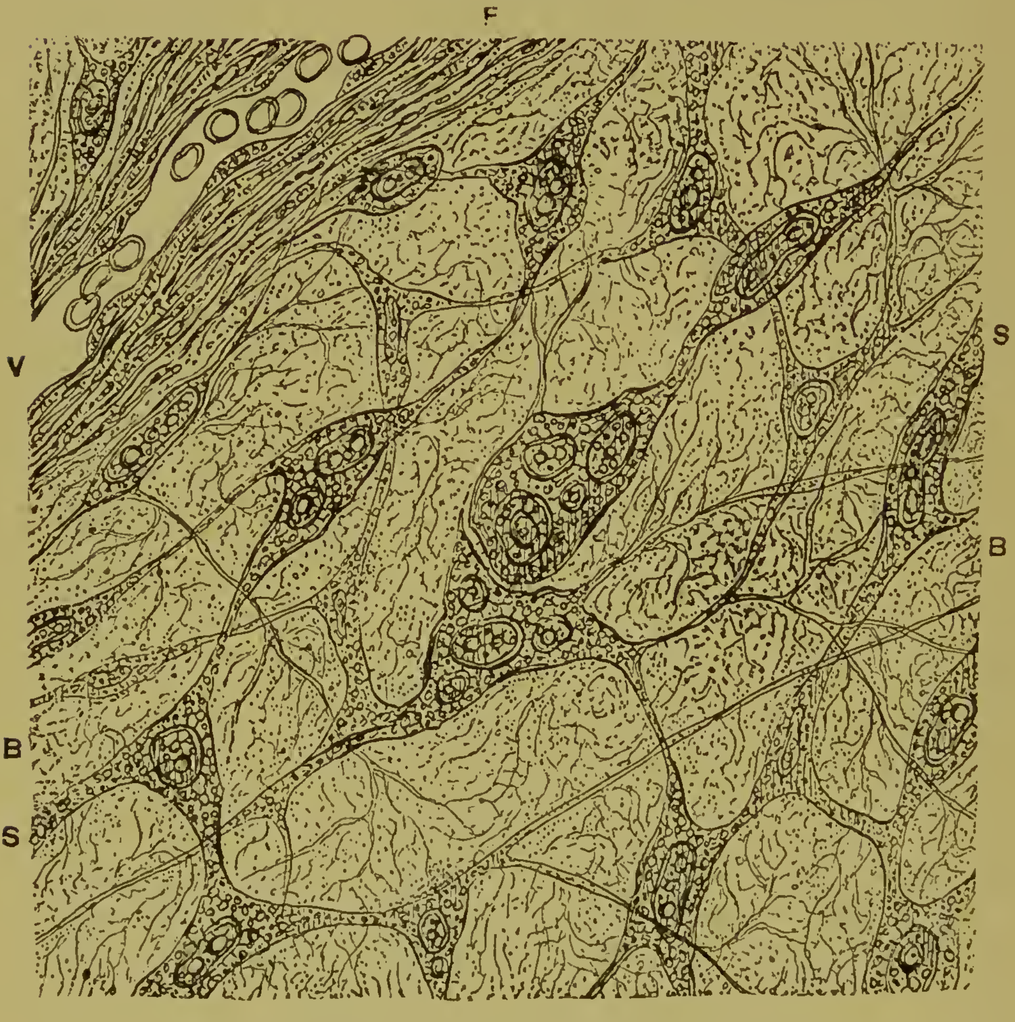
C, *C*, cavernous spaces filled with venous blood; *V*, *V*, capillary blood-vessels of the trabeculæ bounding the cavities; *E*, *E*, endothelia in transition, partly into myxomatous and partly into fibrous connective tissue. Magnified 500 diameters.

its transformation both into myxomatous and fibrous connective tissue. This portion of the tumor contains solid masses of a dense fibrous connective tissue, which in all probability are not newly formed, but represent residues of the former tissue of the gum or the periosteum.

VIII. Myeloma.—These tumors are by no means of rare occurrence, as shown by our comparatively small collection, which embraces five specimens of myeloma and its combinations out of seventeen representatives of tumors in general. All these tumors are considered malignant with but one exception, which concerns the variety termed "epulis sarcomatosa," or, as we propose to call it, fibro-myeloma. This variety is well known to surgeons as admitting of a radical cure if thoroughly extirpated. Multinuclear bodies are of such frequent occurrence that an authority like Virchow speaks of a variety which he calls "giant-cell sarcoma," growing in the majority of cases from the periosteum. We have described, under a previous heading, benign tumors, especially fibroma, containing a varying number of so-called giant-cells in their juvenile portions, where medullary tissue prevails, and we have emphasized that no stress is to be laid upon the presence of "giant-cells." If the tumor is intermixed with medullary tissue throughout, the diagnosis will be fibro-myeloma, which is still of a low degree of malignity, as shown by clinical experience. We can state positively that the number of multinuclear bodies is of great value for determining the degree of malignity in any given case. The greater their number the surer it is that the tumor is not very malignant, and will not recur if radically removed. On the contrary, the smaller their number the greater is the malignity and the danger of recurrence; whereas, in the worst cases of pure globo- or spindle-myeloma, multinuclear bodies are lacking altogether. In such cases the danger to the life of the patient is imminent, in spite of all attempts at thorough eradication.

According to our nomenclature, we will dwell upon combinations such as myxo-, fibro-, and osteo-myeloma, and at last consider the two purely malignant forms,—viz, globo- and spindle-myeloma. Either of these forms may arise primarily from the periosteum or medulla of the jaw-bones, or start in the nasal cavity, the antrum of Highmore, or the soft palate, and invade the upper jaw in a secondary manner. In several instances of primary myeloma we found, in the tissue of the tumor, clusters of pigment indicative of a previous hemorrhage, possibly in connection with a traumatism (blow, kick, fall, etc.), which, as is admitted, often causes—for reasons unknown—the growth of malignant tumors.

Fig. 301.



Myxo-Myeloma of Upper Jaw filling the Antrum of Highmore.

F, tract of fibrous connective tissue; *V*, capillary blood-vessel; *S*, *S*, nucleated protoplasmic tracts branching and finely interconnecting; *B*, *B*, myxomatous basis-substance with a delicate reticulum in connection with the protoplasmic bodies. Magnified 1200 diameters.

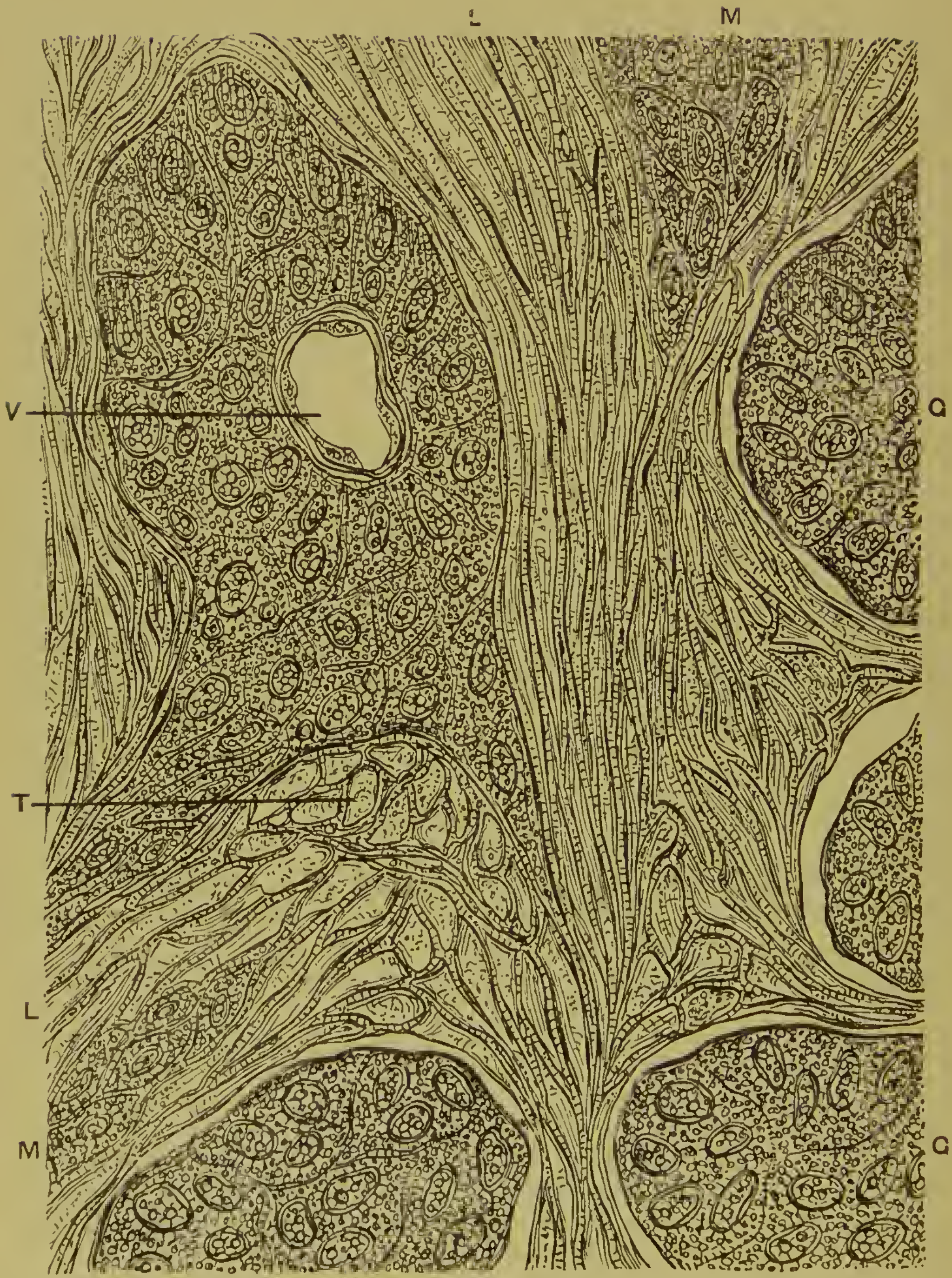
a. Myxo-Myeloma.—This specimen originally started on the soft palate of a young lady near twenty years of age, and after extirpation recurred on the base of the upper jaw-bone, invading in turn both the antrum and the nasal cavities. With low powers of the microscope the tumor shows a thin investment of fibrous connective tissue, fibers from which penetrate the morbid growth, scantily supplied with blood-vessels, and producing imperfect septa, by which an indistinct alveolar structure results. The alveoli are filled with protoplasmic bodies, either globular or spindle-shaped, or provided with numerous offshoots, by means of which a net-like structure is established. (See Fig. 301.)

Globular corpuscles are arranged in clusters, with a scanty intervening basis-substance. Spindle-shaped corpuscles are arranged in tracts, freely connecting at acute angles, and separated from one another by a slight amount of a finely-granular basis-substance. This latter form would correspond to that variety of myeloma termed by Virchow "net-celled sarcoma." The prevailing formation within the alveoli, however, corresponds to the illustration, being composed of very large polymorphous protoplasmic masses, some containing a number of nuclei, and interconnected by comparatively narrow offshoots in all directions. The basis-substance between these formations is conspicuous, and traversed by an extremely delicate reticulum, which arises from the finest offshoots in a brush-like manner. This tissue is myxomatous in structure, the predominance of which over the structures before mentioned entitles the tumor to the name of myxo-myeloma. The myxomatous tissue contains no blood-vessels, which invariably run in tracts of fibrous connective tissue, at rather distant intervals. As the consistence of the tumor was soft, almost jelly-like, the basis-substance must be of the mucoid or myxomatous variety. In cases where the basis-substance is more firm the tumor has been termed chondro-myeloma, or malignant chondroma, although we would consider the latter term as illogical.

b. Fibro-Myeloma.—Among several tumors of this variety, we have selected the present specimen for description, its clinical history being better known. It was located upon the right side of the lower jaw of a man about thirty-five years of age, the size of half a hen's egg, occupying the space between the first bicuspid and the ramus; the teeth in this locality having previously been removed. Its consistence was firm, its surface slightly nodular, its color purple, and there were nowhere signs of ulceration. For a while previous to its removal it caused considerable pain of a shooting character. It had grown within about two years.

Under the microscope the tumor appears to be composed of

Fig. 302.



Fibro-Myeloma with Multinuclear Bodies from the Lower Jaw.

L, *L*, longitudinal, *T*, transverse sections of bundles of fibrous connective tissue; *M*, *M*, clusters of medullary corpuscles; *G*, *G*, multinuclear bodies or so-called giant-cells, retracted from the adjacent connective tissue; *V*, blood-vessel in transverse section surrounded by a cluster of medullary corpuscles. Magnified 1200 diameters.

interlacing tracts of fibrous connective tissue, with interstices filled either with medullary corpuscles or with multinuclear protoplasmic bodies; the fibrous portion everywhere being in excess over the medullary tissue. (Fig. 302.) The clusters of medullary corpuscles are rather numerous, exhibiting an endothelial appearance. In some places blood-vessels are seen to be surrounded with or accompanied by such medullary corpuscles, and in a few places multinuclear bodies are visible in small numbers, but in a remarkably regular arrangement. The fact that blood-vessels traverse the clusters excludes their being of an epithelial nature, and therefore the diagnosis of cancer, which could be made upon a superficial glance at the tumor, is untenable. This tumor we would not consider a very malignant one, and the diagnosis of a fibroma would be admissible if the medullary nests were not so profusely scattered throughout the tissue.

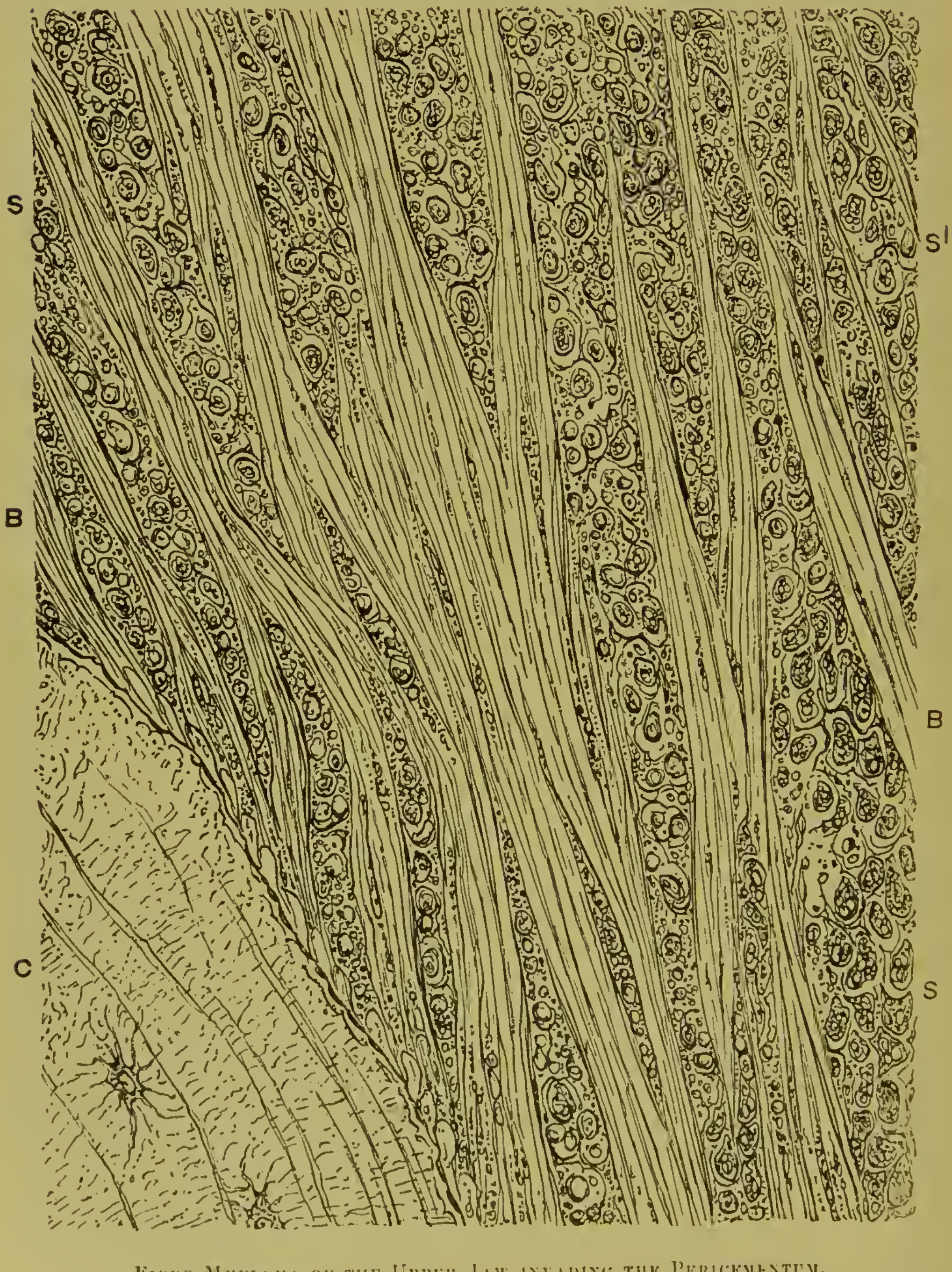
A far more malignant case of fibro-myeloma is the following: A man about twenty-five years of age showed a hard swelling upon the right upper maxilla, which had developed within three years. The tumor occupied not only the region of the alveolar process, but also the antrum of Highmore. Most of the teeth had become loose and been removed, the two last molars being left, but very loose, and nearly imbedded in the dark-red mass of the tumor. The diagnosis was malignant tumor, either cancer or myeloma. The entire right maxilla was extirpated, and a portion of the alveolar process with a tooth in it came into our possession.

At the microscopical examination no trace of a bony structure could be found; the mass of the tumor consisting mainly of clusters of small globular shining corpuscles, between which an indistinct fibrous reticulum was discernible. The clusters were separated from one another by bundles of fibrous connective tissue, greatly varying in amount; the surface of the tumor was bordered by an indistinct capsule of the same tissue, which itself contained smaller clusters of myeloma corpuscles, and showed irregular, blunt elevations belonging to the gum, and covered with a thin layer of stratified epithelium.

In the neighborhood of the tooth the pericementum was still recognizable, in the shape of straight bundles of fibrous connective tissue, still in connection with the cementum, but crowded with myeloma corpuscles. (See Fig. 303.)

In this situation it is evident that the tissue of the myeloma grew at the expense of the fibrous connective tissue of the pericementum. In some places the bundles of the latter tissue are still broad, containing in their middle slit-like groups of medul-

FIG. 303.



FIBRO-MYELOMA OF THE UPPER JAW INVADING THE PERICEMENTUM.

C, cementum; *B*, *B*, bundles of fibrous connective tissue; *S*, *S*, clusters of myeloma corpuscles between the bundles; *S*^{1}, transformation of the bundles into the tissue of myeloma, with scanty traces of the bundles. Magnified 500 diameters.

lary corpuscles. In other places these corpuscles have replaced the bundles to a great extent; in still other places, only scanty and thin bundles are seen traversing the tissue of the myeloma. At the last elements of myeloma occupy large fields, with scanty or no fibrous tissue between them. Obviously the process of transformation is explicable only if we admit that the whole of the fibrous connective tissue, the protoplasmic bodies as well as the basis-substance, is supplied with living matter, from which the new formation of the medullary corpuscles takes its origin.

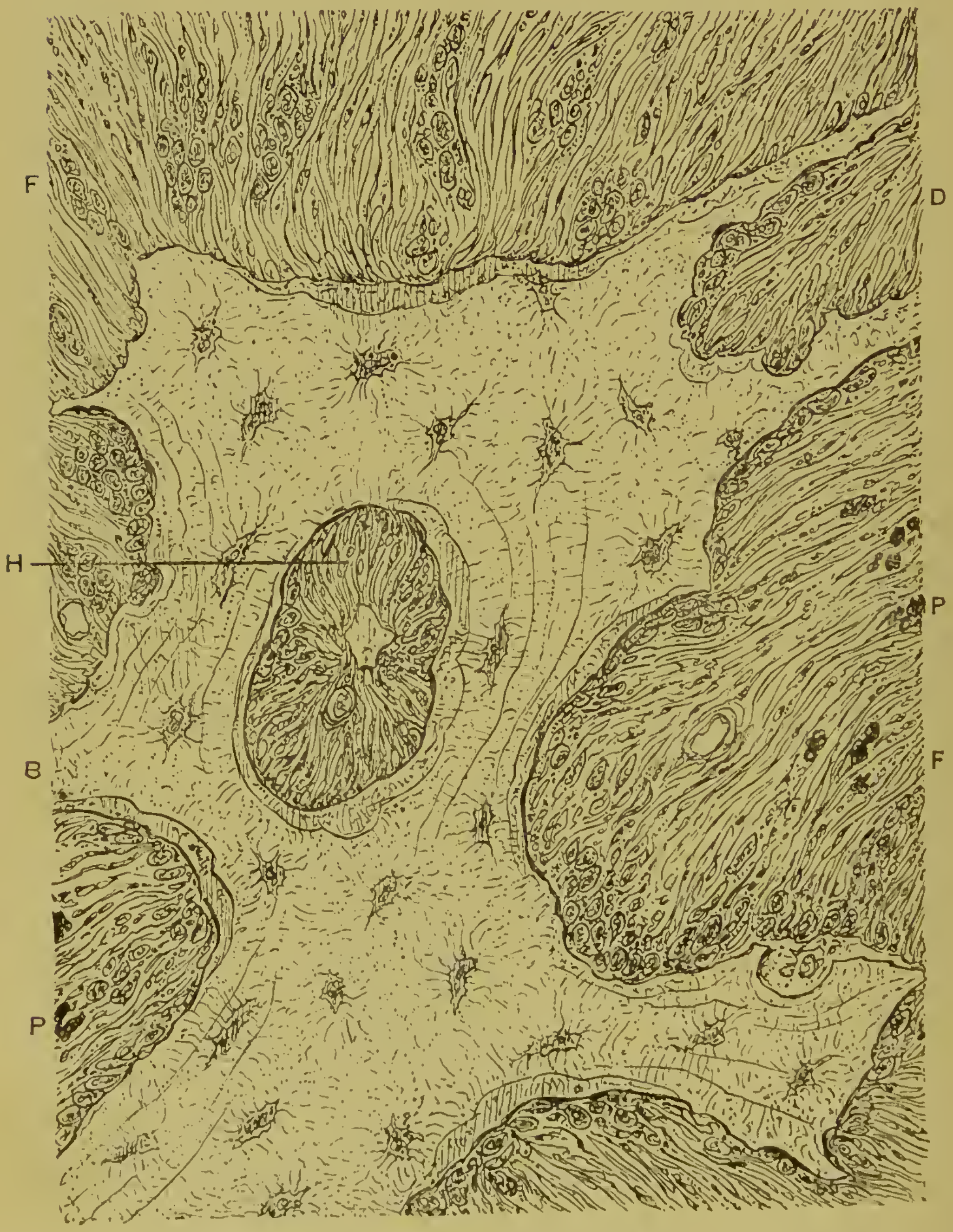
If we confine ourselves to the examination of a limited portion of this tumor, no differentiation between myeloma and an acute inflammatory process can be made out, since the medullary corpuscles constituting myeloma are identical with inflammatory corpuscles about ready to break up into pus. It should also be borne in mind that a rapidly-growing cancer may change its character into that of a myeloma, or fibro-myeloma, as first stated by Virchow. In specimens of such rapidly-growing tumors we have always to keep a sharp lookout for epithelial nests, the presence of which would be evidence of cancer. Should such nests be absent, we diagnosticate myeloma. We are, however, aware that either of these tumors involves considerable danger to the life of the patient.

c. Osteo-Myeloma.—This tumor was found in the mouth of a lady aged about thirty, in the region of the bicuspids upon the left upper jaw, and had reached the size of half a robin's egg in a year and a half, the teeth having previously been removed. The tumor exhibited the structure of a fibro-myeloma, invading mainly the alveolar process, which was reduced to minute remnants of bone scattered throughout the tissue. (See Fig. 304.)

The term osteo-myeloma is confined to growths primarily arising in the medulla of bone, or to growths holding newly-formed bone-tissue. As the tumor in this instance started in the medulla of the alveolar process, and is largely intermixed with fibrous connective tissue, its proper title would be osteo-fibro-myeloma. The remnants of bone-tissue give evidence of its transformation into the mass of the tumor through the intervening stage of medullary tissue. In a few places we find near the border of trabeculæ enlarged lacunæ containing several medullary corpuscles, obviously sprung from previous bone-corpuscles, and still surrounded by a calcified basis-substance.

In other places a number of bone-corpuscles are seen connected by means of broad offshoots into chains. In still others, the first step toward the dissolution of the bone-tissue is the appear-

FIG. 304.

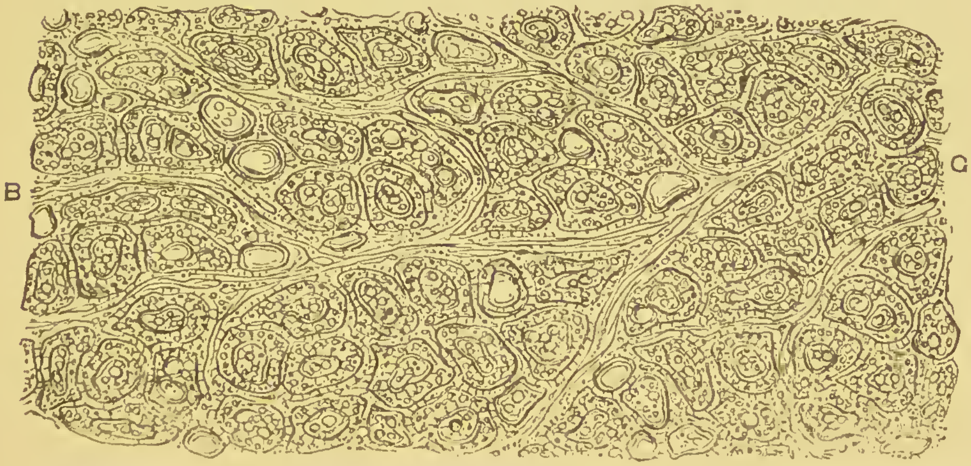


OSTEO-FIBRO-MYELOMA OF THE ALVEOLAR PROCESS OF THE UPPER JAW.

F, F, fibrous connective tissue with numerous clusters of medullary corpuscles; *P, P*, clusters of pigment-granules; *B*, trabeculæ of bone indistinctly lamellated, with normal bone-corpuscles; *H*, medullary space with central blood-vessels; *D*, bay-like excavation of the bone. Magnified 500 diameters.

ance of bay-like excavations corresponding to a previous territory, in which protoplasm makes its appearance; or the border of the bone is split up into a number of medullary corpuscles, which are not yet entirely freed from basis-substance. All this is strong proof that the bone actively participates in the new formation of the morbid tissue, the same as it participates in the process of inflammation. To say, as some authors do, that the bone is simply eaten up from without by the newly-formed tissue, does not prove much acuteness of observation, since it is by no means difficult to satisfy one's self as to the active proliferation of the bone-corpuscles within the lacunæ. It is invariably the medullary corpuscles that first appear from bone-tissue, and by subsequent splitting into spindles and reinfiltration with basis-substance give rise to the fibrous portion of the morbid growth.

FIG. 305.



GLOBO-MYELOMA OF THE PERIOSTEUM OF THE ALVEOLAR PROCESS OF THE UPPER JAW.

B, delicate bundles of fibrous connective tissue; *G*, globular corpuscles of myeloma in different stages of development. Magnified 1200 diameters.

d. Globo-Myeloma.—This specimen was obtained from a tumor taken from the mouth of a young lady about twenty years of age. It was located on the right upper jaw, in the region of the bicuspids, and had grown to the size of half an English walnut in about two years. The teeth had previously been removed. It was diffusely infiltrated toward the neighboring tissue, and evidently started from the periosteum. (See Fig. 305.)

The most striking feature was the scarcity of fibrous connective tissue, which in delicate bundles traverses the growth without any regularity. The main mass is composed of medullary corpuscles, either globular or polygonal, the latter produced by mutual pressure. Between small groups of such corpuscles extremely delicate septa of fibrous tissue are visible, in which the blood-vessels are located, though present only in small numbers.

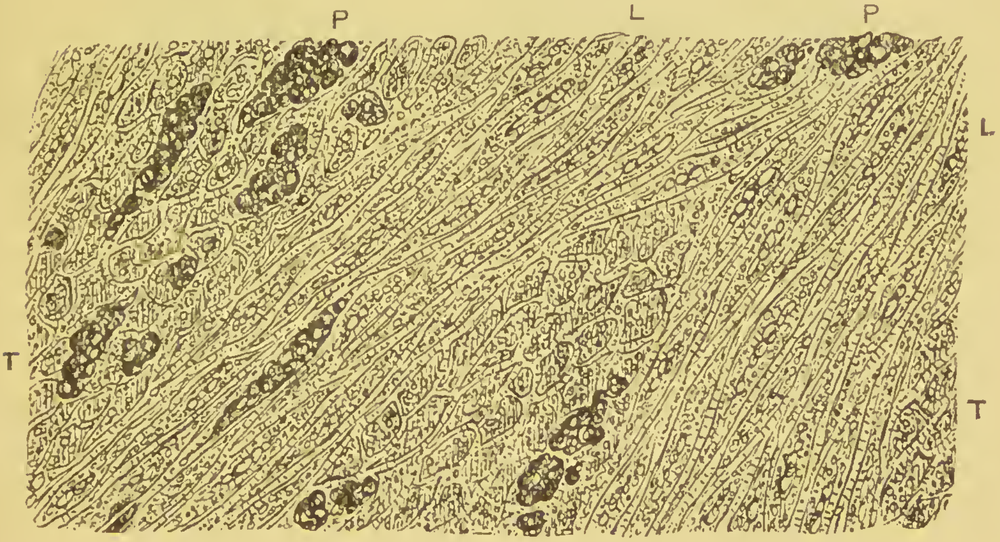
Higher powers reveal two facts,—viz, first, that the corpuscles are interconnected by delicate radiating offshoots, traversing the narrow spaces between them; second, that in a limited field of the tissue all stages of development of myeloma can be made out.

We see small granules of a high refraction, structureless, not even reaching the size of red blood-corpuscles. We see larger granules and lumps with a varying number of vacuoles in their interior. We furthermore see lumps with large, compact nuclei, and at last corpuscles with reticulated nuclei, with granules in their interior, and of the ordinary reticulated structure of protoplasm. Any granule within the protoplasm may grow to the size of a nucleus, or a nucleated corpuscle; the nuclei themselves are in an active process of division, as shown by numerous dumb-bell forms, and figures of double or treble nuclei within a single corpuscle. All this is proof of a very rapid multiplication of the corpuscles, causing an extremely rapid growth of the tumor, and indicative of a high degree of malignancy. In accord with the latter features, not a single multinuclear body or "giant-cell" can be seen, not even where somewhat broader bundles of fibrous tissue, probably belonging to the periosteum, are present.

c. Spindle-Myeloma.—This tumor, corresponding to what Virchow has termed "spindle-celled sarcoma," is represented in our collection by a specimen, the history of which is unknown to us. All we can say is that it had grown in the upper jaw. (See Fig. 306.)

The tumor is largely composed of spindles, but in some places globular corpuscles are seen, which feature would entitle the tumor to the name of a combined globo- and spindle-myeloma. The tumor has comparatively little of fibrous connective tissue, in which scanty blood-vessels are coursing. The spindles are arranged in interlacing groups,—in almost every field we meet with longitudinal and transverse sections of spindles, all of which are interconnected by delicate offshoots. The rapid growth of the tumor is indicated mainly by coarsely-granular nuclei, or chains of coarse granules, replacing the nuclei. In some places clusters of red-brown pigment-granules are seen, but in such small numbers that the tumor cannot be properly called pigmented or melanotic myeloma. The pigment appears either in spindle-shaped or irregular clusters, partly within and partly between the spindle-shaped corpuscles. These pigment-clusters are unquestionably the result of a previous hemorrhage, possibly caused by a mechanical injury, giving issue to the myelomatous new growth.

FIG. 306.

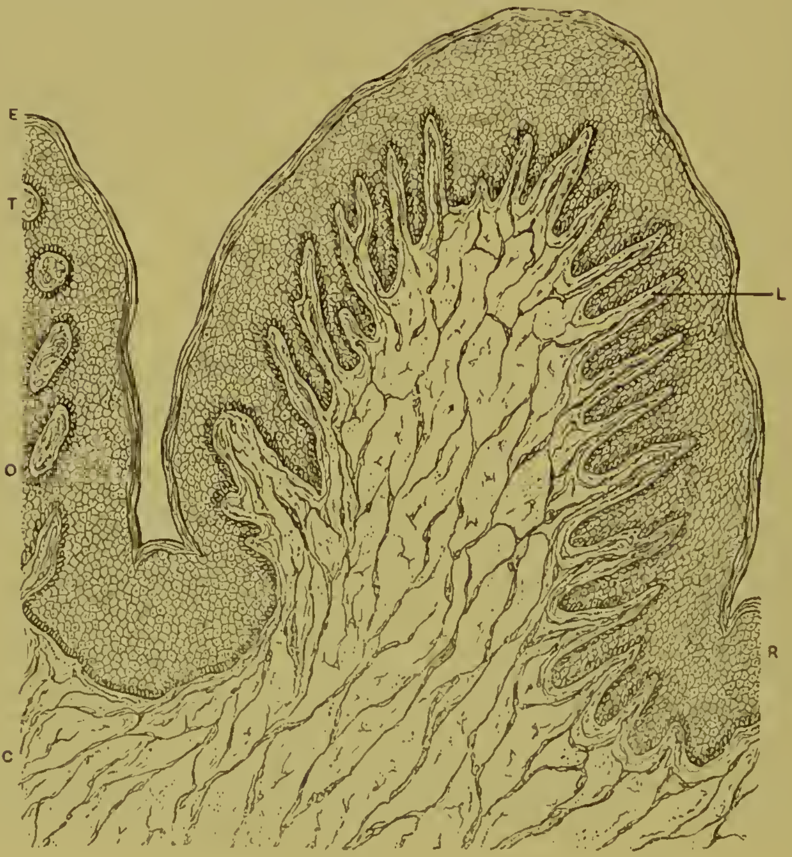


SPINDLE-MYELOMA OF UPPER JAW.

L, *L*, longitudinal sections of spindles; *T*, *T*, transverse sections of spindles; *P*, *P*, clusters of pigment from previous hemorrhage. Magnified 1200 diameters.

IX. Papilloma or Warty Tumor is rare upon the mucous membrane of the oral cavity. By direct venereal infection the tonsils and the soft palate of women may become covered with so-called venereal warts, which in fact are papillary outgrowths of the oral mucosa, sometimes attaining the size of a pea, and being present in large numbers. In men, upon the mucosa covering the hard palate, warty tumors not of venereal origin have been observed, varying from the size of a pin-head to that of a split pea. The specimen from which the illustration is taken was of the latter size, and had grown upon the hard palate of a middle-aged married man. (See Fig. 307.)

FIG. 307.



HORNY PAPILLOMA OF HARD PALATE OF A MAN.

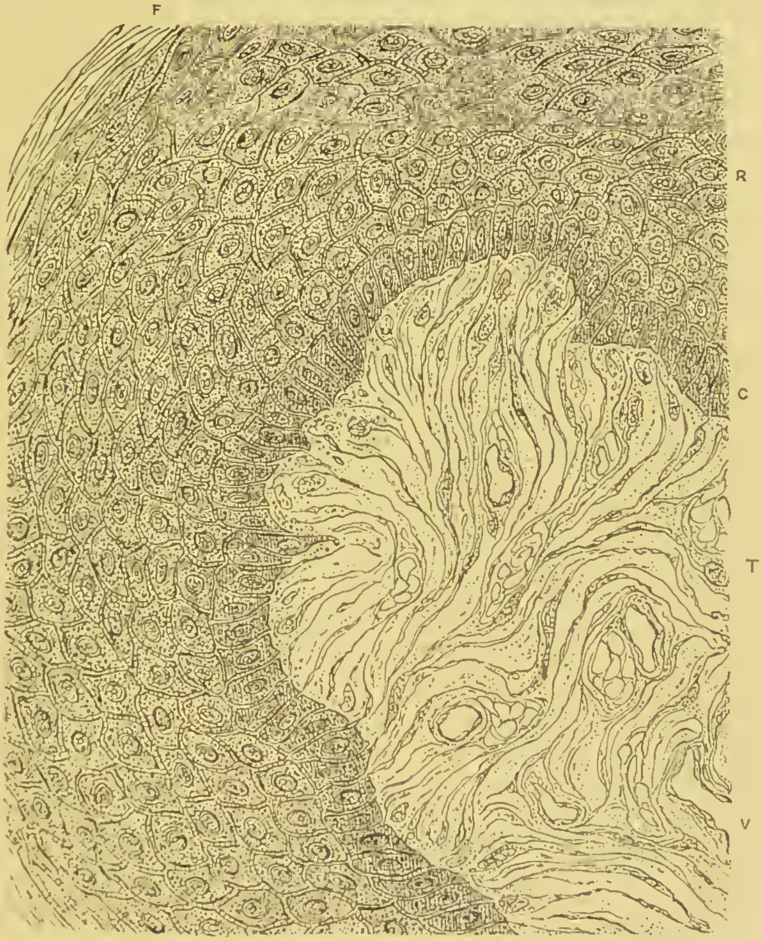
E, epidermal layer; *R*, rete mucosum; *L*, papilla in longitudinal section; *O*, papilla in oblique section; *T*, papilla in transverse section; *C*, fibrous connective tissue. Magnified 50 diameters.

The characteristic feature of such tumors is their warty surface, owing to the presence of papillæ covered with a heavy layer of stratified epithelia. The papillæ are outgrowths of the connective tissue of the mucous membrane, and are often richly supplied with blood-vessels. (See Fig. 308.)

Tumors of papillary structure are known to be difficult of eradication. Unless thoroughly extirpated they are prone to recur, and repeated attempts at eradication may cause a change of the tumor into a malignant cancer, generally of the type of epithelioma.

X. Cysto-Adenoma.—Glandular tumors of the jaws, the mucous membrane of which abounds in mucous glands, are nevertheless of rare occurrence. A combination of adenoma with cystic cavities is extremely rare. The case to be considered came under the observation of Dr. Wm. Carr, who kindly furnished the details of the history, and supplied me with a freshly-excised piece of the tumor for study. The tumor had begun to grow upon the left side of the lower jaw, behind the second molar, when the patient was seventeen years of age: and

FIG. 308.



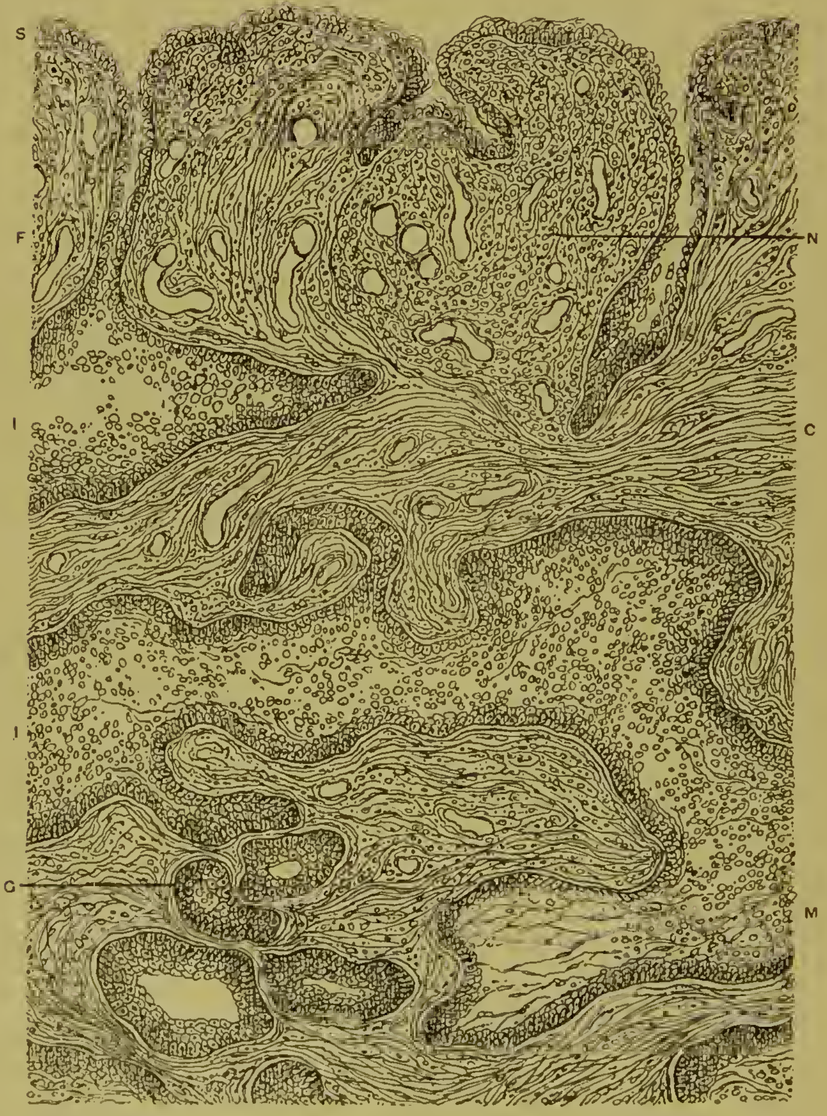
HORNY PAPILLOMA OF HARD PALATE.

T, papilla in transverse section; bundles of fibrous tissue in longitudinal and transverse section, with protoplasmic tracts between the bundles; *V*, capillary blood-vessel; *C*, row of columnar epithelia; *R*, rete mucosum composed of cuboidal epithelia; *F*, horny layer, composed of flat epithelia. Magnified 500 diameters.

when he had reached the age of nineteen, it had grown to the size of a goose's egg. It was soft and fluctuating to the touch, and bled profusely upon the slightest mechanical injury.

The basis of the cyst, from which the specimen was taken, proved to be made up largely of acinous glands of great irregularity, lined partly by cuboidal and partly by short columnar epithelia. (See Fig. 309.) With higher powers of the micro-

FIG. 309.

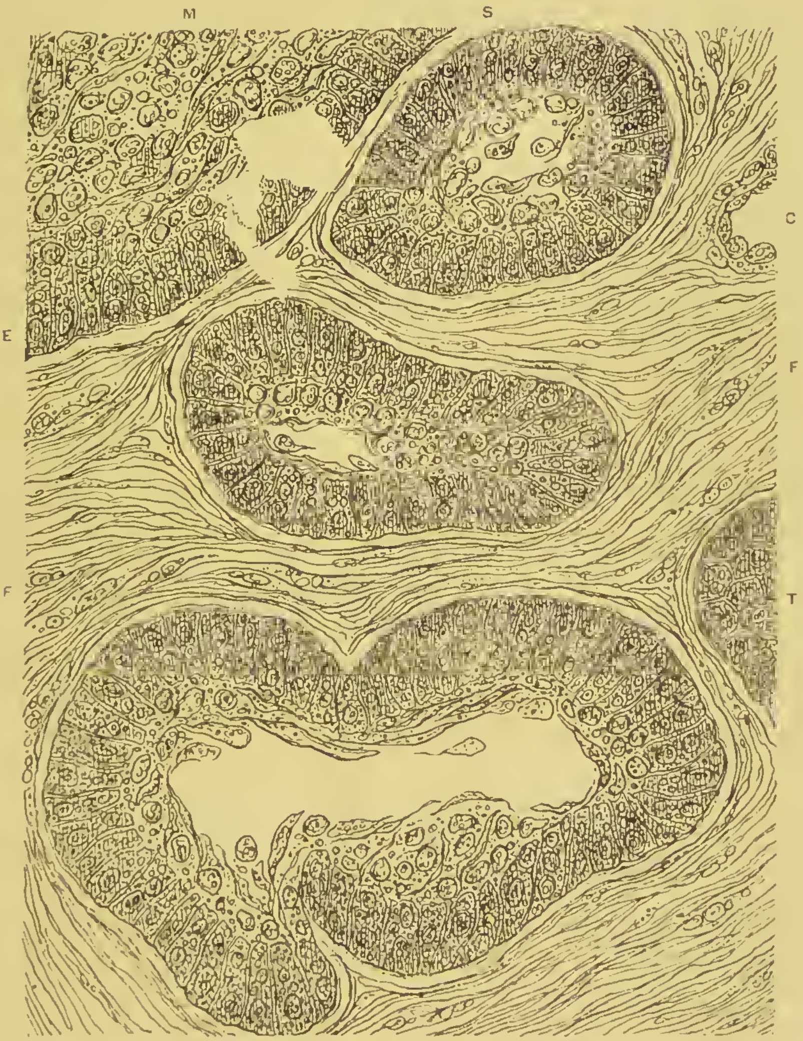


CYSTO-ADENOMA OF LOWER JAW.

S, surface toward cystic cavity, with numerous epithelial prolongations; *F*, myxo-fibrous connective tissue; *N*, nodule of myxomatous tissue, freely vascularized; *C*, fibrous connective tissue; *I*, *I*, enlarged glandular cavities filled with indifferent elements; *M*, myxomatous tissue, sprung from epithelia; *G*, unchanged glandular formations. Magnified 50 diameters.

scope a peculiar change of the epithelia became noticeable, much resembling that of the epithelia of the enamel-cord preceding the production of the enamel-organ in the normal development of the teeth. In the tumor a great many epithelia were transformed into solid indifferent or medullary corpuscles, from which, in turn, myxomatous tissue developed. Close to the lining epithelia we frequently meet with a layer bearing resemblance to the intermediate layer of the enamel-

FIG. 310.



CYSTO-ADENOMA OF LOWER JAW.

E, row of columnar epithelia lining the gland; *T*, top view of columnar epithelia; *M*, medullary tissue, sprung from epithelia; *S*, basement-membrane around the glands; *F*, *F*, fibrous connective tissue between the glands; *C*, capillary blood-vessel in transverse section. Magnified 500 diameters.

organ. By a gradual liquefaction of the myxomatous tissue cystic cavities of varying sizes arise, and, no doubt, the main cystic cavity in this case owed its origin to such a change in the intra-glandular myxomatous tissue. (See Fig. 310.)

XI. Carcinoma.—This type of tumors is characterized by the presence of epithelial nests, scattered without regularity in the connective tissue, which may be either myxomatous or fibrous. Most pathologists claim that cancer may originate only in such tissues as are covered with or contain normal epithelia. The mucosa of both the oral and nasal cavities is the starting-point of cancerous growths, and in the upper jaw there is an additional source in the mucosa of the antrum. Again, the cancer may be primary in the tissue just named, or secondary by invasion from the skin or any glandular formation,—for instance, from the salivary glands.

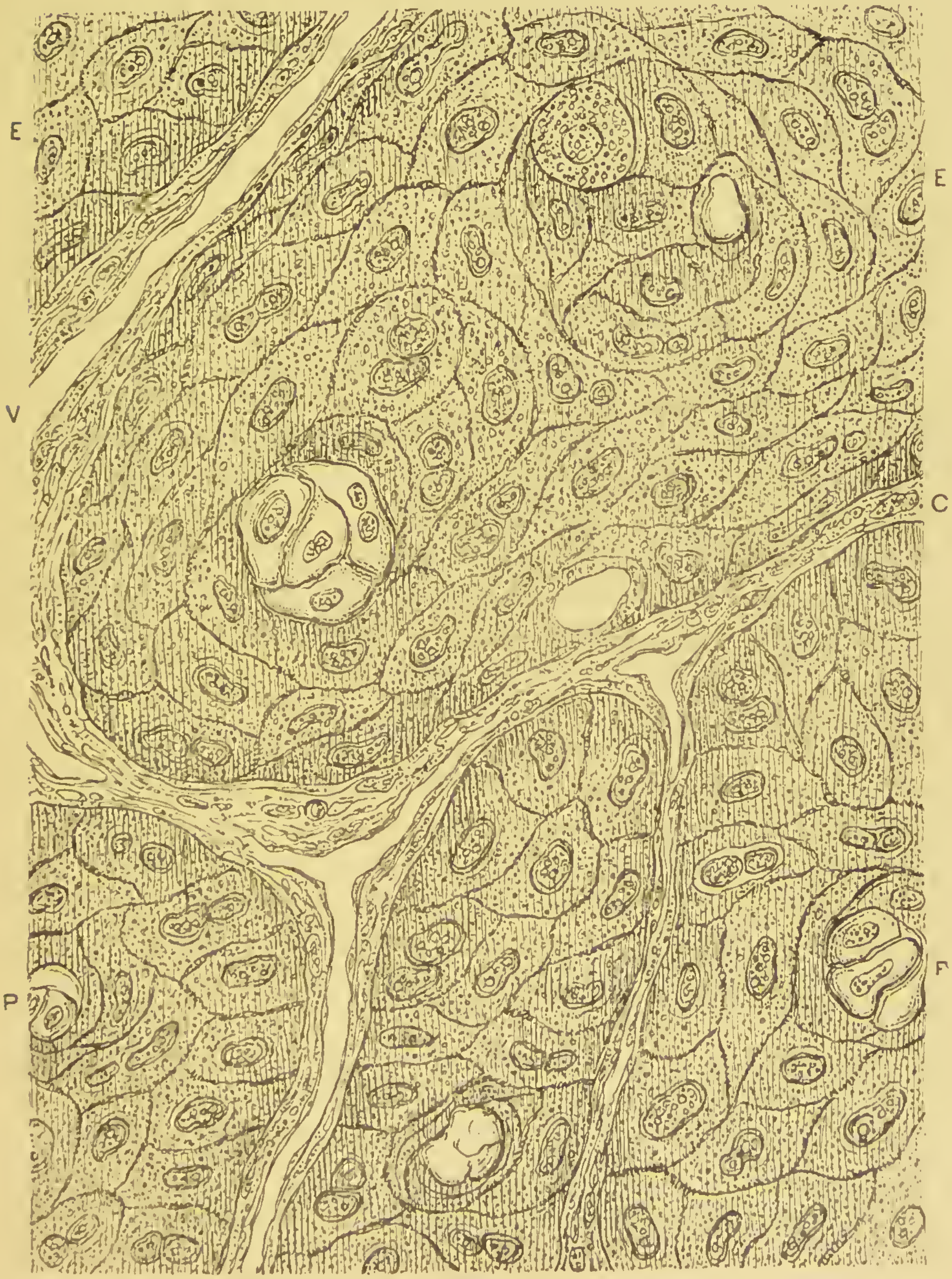
There are three varieties of cancer recognized by modern pathologists,—viz, first, scirrhus, with comparatively small nests of epithelia, and a large amount of fibrous connective tissue around the nests; second, epithelioma or dermoid cancer, with concentrically-arranged flat epithelia filling the nests, and a varying amount of fibrous tissue between them; and, third, medullary cancer, with small and irregular epithelia in the nests, and a scanty fibrous tissue between them. Of these three varieties our collection has two,—viz, epithelioma and medullary cancer, both having reached the upper jaw from adjacent epithelial structures, skin and mucous membrane.

a. Epithelioma, or Dermoid Cancer.—We have two examples of this type of cancer, both from men over forty years of age. In one the tumor arose in the mucosa of the antrum, and in the other in that of the floor of the nasal cavity, both being similar in structure. (See Fig. 311.)

In viewing a specimen of epithelioma from the mucosa of the antrum, we observe marked differences in the structure of the epithelia. Near the boundary toward the connective tissue they are smaller and narrower than in the middle portions of the nests. They are often replaced by a row of medullary corpuscles, to such an extent that no sharp boundary line exists between the connective tissue and the epithelial nest. This obviously means a gradual transformation of the medullary into epithelial tissue, a process which leads to increase of the bulk of the nests and a decrease of that of the connective tissue. At last, the blood-vessels being finally obliterated, the nests are deprived of nourishing material, and a local necrosis—viz, ulceration—takes place, which is a common feature in all cancers.

The second prominent feature is an active new formation of

FIG. 311.



EPITHELIOMA OF THE MUCOSA OF THE ANTRUM.

C, delicate fibrous connective tissue crowded with medullary corpuscles; *V*, capillary blood-vessel in the connective tissue; *E*, *E*, epithelial nests made up of concentrically-arranged flat epithelia; *P*, *P*, cancer-pearls composed of changed epithelia. Magnified 500 diameters.

living matter in the epithelia. This causes the nuclei to become homogeneous; then to assume an hour-glass shape, and lastly a division into several nuclei. Not infrequently we see several nuclei or several medullary corpuscles within a considerably enlarged epithelium. Such formations have been termed "mother-cells" by previous pathologists, whereas to-day we know that they are the outcome of an active endogenous new formation. Around the nucleus often are seen vacuoles, or plasmatic spaces, which evidently contain nourishing liquid, enabling the nucleus to rapidly increase its amount of living matter, with the result of fission and division, with a rapid new formation of epithelia. Except where the nucleus is surrounded by a vacuole, it is in connection with the adjacent protoplasm of the epithelium, by means of delicate conical offshoots. Similar offshoots also traverse the cement-substance between the epithelia, thus uniting all into a continuous mass of protoplasm. The central portions of the nests often contain groups of epithelia, which have assumed a high degree of refraction, a yellowish color, and a homogeneous appearance. At first the nuclei remain, though faintly discernible; but in the more advanced degrees of this metamorphosis even the traces of nuclei are lost, and a certain number of epithelia are transformed into structureless glistening plugs, representing the well-known cancer-pearls. The nature of this process is not yet known.

The connective tissue is either of the myxomatous or fibrous variety, never very rich in blood-vessels; mainly capillaries and veins. In many places the connective tissue is crowded with medullary or lymph-corpuscles, between which a delicate reticulum is seen. Some authors claim that this is the result of an inflammatory reaction of the epithelial upon the connective tissue; whereas we claim that it is the medullary condition of the connective tissue from which new epithelia arise. We base our views upon direct observation, since we know that if, after removal of a cancer, lymph-corpuscles be left behind, even though at a great distance from the cancer itself, the disease will invariably recur. This fact urges the necessity for removal of large portions of tissue in the neighborhood of cancer. Modern surgeons, by clinical experience, have reached the same conclusion, which they consider the only safeguard against relapses, so very common in this disease. Unfortunately, we are not able to say why the lymph-corpuscles or the medullary tissue, into which the connective tissue is transformed in an almost identical way with inflammatory infiltration, should have such a marked capacity for changing into epithelia; in other words, wherein the contagion of the tissue lies.

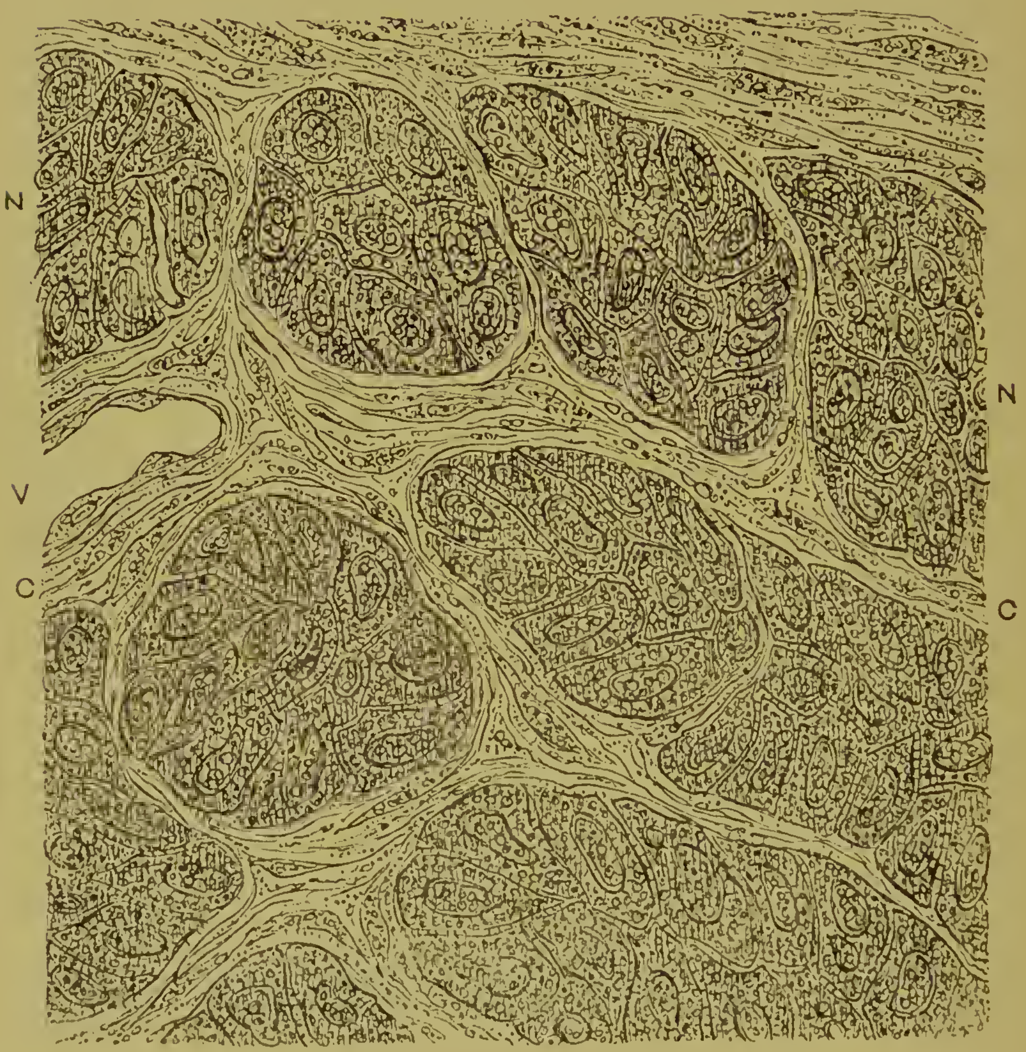
b. Medullary Cancer.—Our specimen is taken from the enormously enlarged alveolar process of the upper jaw of a man over sixty years of age. Twelve years previous to his death he was first operated upon for a so-called rodent ulcer, upon the left wing of the nose, which about fifteen years previously had originated from a slight injury, causing a shallow ulcer, which could never be induced to heal. The scooped-out particles of tissue from the first operation were examined under the microscope, and showed the structure of a shallow or flat epithelioma, which previous authors termed "rodent ulcer."

Repeated recurrences and operations took place afterward, until the left upper jaw began to swell, the left eye was pushed up and forward, and the teeth became so loose and troublesome that they had to be removed. The swelling of the face proved to be greatly augmented by an apparently long-standing abscess in the antrum, the result of the death of a second molar many years before, the roots of which penetrated its floor. Upon the removal of this tooth a large quantity of fœtid pus escaped, and a temporary improvement was the result. Later the swelling invaded the front of the mouth and passed to the right side to such a degree that several operations were required to remove the fungoid, easily-bleeding masses of the alveolar process, gum, and hard palate, which were almost choking the patient. The purpose of these operations was not to remove the cancer, but to prevent death from suffocation or starvation. This tumor is a type of medullary cancer. (See Fig. 312.)

The specimen exhibited in some places an almost unchanged stratified epithelium covering the papillæ of the gum. In other places the papillæ were much enlarged and flattened. Still further, the papillæ have entirely disappeared and the epithelial layer is considerably thinned, until at last the epithelium has disappeared, and an ulcerating cancer-tissue appeared upon the surface. In those places where the epithelial stratum of the gum appears thinned, the deepest or columnar row of epithelia as well as the lower layers of cuboidal epithelia are absent, and are replaced by a medullary tissue of a myxomatous character, which has incidentally sprung from the previous epithelia.

We feel the more confident of such change having taken place from the fact that at the border between the epithelial and medullary tissues the epithelial bodies themselves show a marked increase of living matter, and a gradual transformation into medullary corpuscles.

Fig. 312.



Medullary Cancer of the Left Upper Jaw, invading the Alveolar Process and Gum.

N, *N*, nests of irregular polyhedral epithelia; *C*, *C*, delicate fibrous connective tissue between the nests; *V*, vein. Magnified 1200 diameters.

Close beneath the medullary layer nests of epithelia make their appearance, separated from one another by, first, medullary, and deeper down by a delicate fibrous connective tissue, which latter has evidently originated from the former. We therefore maintain that a medullary tissue which arose from previous normal epithelia may change into fibrous connective tissue, and *vice versa*, that medullary tissue which arose from connective tissue may eventually be converted into epithelia of cancer.

The medullary nests are made up of very irregular bodies, which by pressure have assumed a polygonal form. In many instances a whole nest or a portion of it is made up of granular protoplasm, with nuclei scattered at regular intervals, without any intervening cement-substance. Where the latter is present in the shape of a narrow ledge, it is invariably pierced by delicate offshoots or thorns, interconnecting the single epithelial elements. The changes of the epithelia toward proliferation are much the same as in the epithelioma before described. The connective tissue shows a transformation into lymph-tissue to a great extent. Where it has retained its fibrous character it is scanty, separating the epithelial nests and carrying a large number of protoplasmic bodies. The blood-vessels running therein are scanty, and prevailingly capillaries and veins. The latter often show sinuous contours, and are replete with blood-corpuscles. As stated under the heading of epithelioma, the secret of the general and local contagiousness of cancer has never been unveiled, but is left for future discovery.

CHAPTER XLVIII.

MALFORMATIONS AND MALPOSITIONS OF THE TEETH.

I. Dwarf Teeth.—In Chapter XVIII, on the development of teeth in embryos affected with rhachitis, dwarf teeth from the lower jaws of a fœtus affected with congenital rhachitis are illustrated and described. In rare instances we find the dentures of adults made up of normal teeth with dwarfed third molars in the upper jaw.*

II. Hyperplasia of Roots.—In Chapter XXX I have copied from Frank Abbott's paper a number of teeth, the roots of which were affected with hyperostosis of the cementum, causing pronounced malformations.

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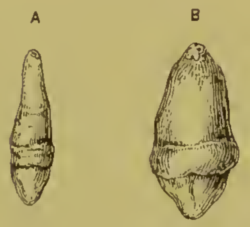
* In Chapter XLVI, Fig. 284, dwarfed and malformed teeth are depicted as found in a dentigerous cyst of the upper jaw.

III. Supernumerary Teeth.—Not infrequently we see supernumerary teeth in temporary dentures, usually behind the upper lateral incisors. Such teeth are smaller than normal ones, and of a more or less conical shape, hence German authors have dubbed them "peg teeth." (See Fig. 313.) In rare cases there are present three bicuspids on one side of the upper jaw, and only one on the other side. Two or even three third molars, or wisdom-teeth, may be found on one side of the upper jaw, while the opposite side has only one. E. Zuckerkandl has seen epithelial germs—*i.e.*, enamel pegs not developed into teeth—behind the third molars.

Fig. 313.

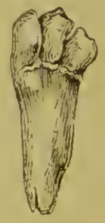


Supernumerary Teeth. (From Wedl.)

A, supernumerary tooth of the right side of the upper jaw, between the first and second bicuspids toward the palate; *B*, supernumerary tooth of the upper jaw, implanted in the palate behind the incisors.

IV. Lobulation of Crowns.—Occasionally the crowns of teeth are divided into finger-like lobules. The illustration (Fig. 314) represents a tooth, probably a bicuspid of the lower jaw, with this anomaly.

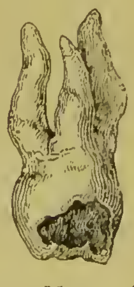
Fig. 314.



Lobulated Crown, probably of a Lower Bicuspid. (From Wedl.)

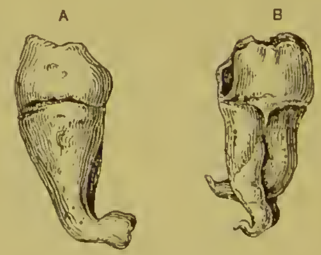
V. Devious Course of Roots.—This anomaly is not very rare, and is a great obstacle to the extraction of the tooth. The deviations are so manifold that a description is scarcely possible. I attach three illustrations, one from a left upper molar of my own collection, and two from Wedl's Atlas. (See Figs. 315 and 316.)

Fig. 315.



Left Upper First Molar (Carious), with Devious Roots.

Fig. 316.

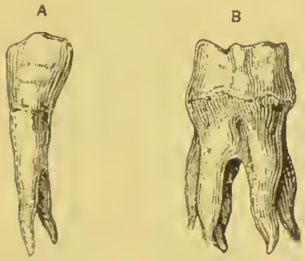


Two Lower Molars with Devious Roots. (From Wedl.)

A, lower third molar with fused roots, hooked and thickened by hyperplastic cementum; *B*, lower third molar, the anterior root pushed through an opening of the posterior, likewise hooked on.

VI. Multiplication of Roots.—This anomaly is by no means rare. I have seen lower lateral incisors with two roots, of which I give an illustration; a lower cuspid with three distinct small roots; a first upper bicuspid with three distinctly separated roots; first lower molar with three pronounced roots, two in the mesial and one in the distal portion of the crown. Wisdom-teeth with as many as five roots are not uncommon. (See Fig. 317.)

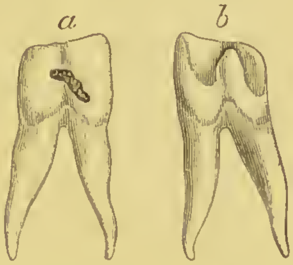
FIG. 317.



TEETH WITH DOUBLE AND MULTIPLE ROOTS.

A, left lower lateral incisor, with double root, symmetrical with the root of the opposite side; *B*, molar of the lower jaw, with five well-developed roots. (From Wedl.)

FIG. 318.

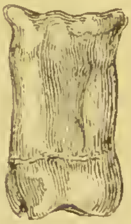


FUSION OF TWO LOWER INCISORS. (From Abbott.)

VII. Fusion of Crowns of Teeth.—Frank Abbott, in the *Dental Cosmos*, 1891, describes two lower incisors fused together at their crowns and necks. (See Fig. 318, *a*, *b*.)

VIII. Fusion of Roots is likewise of not infrequent occurrence, especially in the wisdom-teeth. Fig. 319, taken from Wedl's Atlas, represents an upper molar with a regularly-developed crown and completely-fused roots.

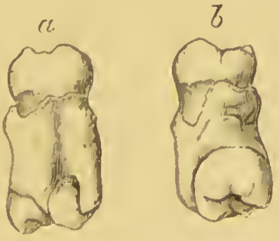
FIG. 319.



UPPER MOLAR WITH FUSED ROOTS. (From Wedl.)

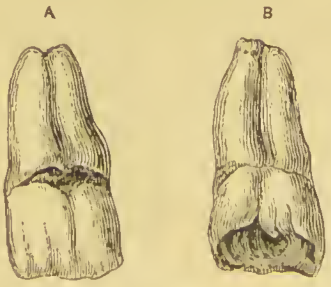
IX. Fusion of Two Teeth.—This anomaly is of rare occurrence. Abbott (*loc. cit.*) illustrates a fusion of the second lower molar with the third molar by hyperplastic cementum. (See Fig. 320, *a*, *b*.) C. Wedl met with a permanent upper central fused with the lateral incisor. (See Fig. 321.)

FIG. 320.



FUSION OF TWO MOLARS. (From Abbott.)

FIG. 321.

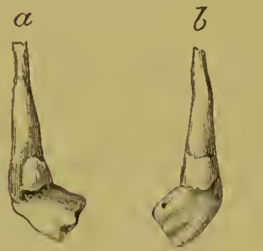


FUSION OF LEFT PERMANENT UPPER CENTRAL AND LATERAL INCISOR. (From Wedl.)

A, labial surface, showing faint line of union of the two teeth; *B*, lingual surface, line of union marked both on roots and crown.

X. Breach in the Continuity of the Crown.—Frank Abbott (*loc. cit.*) illustrates this rare occurrence on an upper lateral incisor, which probably finds its explanation in a fracture or breach of the crown, shortly after its formation, while still covered with soft tissue. (See Fig. 322, *a*, *b*.)

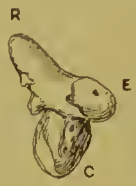
FIG. 322.



BREACH AT THE NECK OF INCISORS. (From Abbott.)

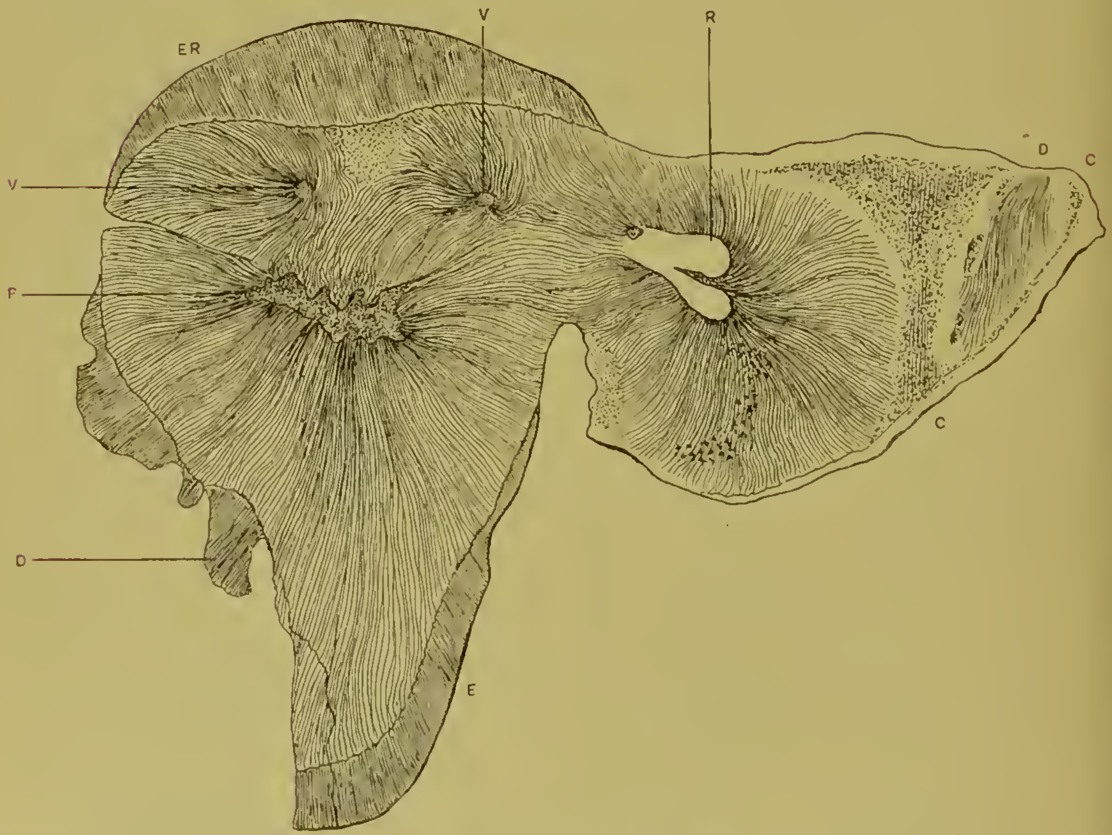
XI. Healed Fractures of Teeth.—A small number of well-observed instances of healed fractures are recorded in the literature. I have chosen for illustration the case of H. Hertz.* The tooth,

FIG. 323.



HEALED FRACTURE OF LEFT UPPER LATERAL INCISOR. (From H. Hertz.) THE TOOTH VIEWED FROM BEHIND AND ABOVE. *C*, crown; *R*, root with two exostoses; *E*, newly-formed enamel-ridge.

FIG. 324.



HEALED FRACTURE OF THE LEFT UPPER LATERAL INCISOR. TRANSVERSE SECTION. (From H. Hertz.)

E, enamel; *ER*, enamel-ridge; *D*, broken-off enamel; *V*, *V*, vascular canals, around which the dentinal canaliculi radiate; *P*, pulp-chamber; *R*, root-canal; *C*, *C*, layer of cementum, between which an island of dentine (*D*, upper) has formed. Magnified 8 diameters.

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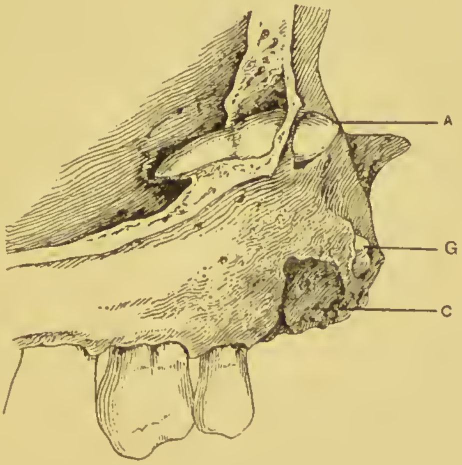
* "Ein Fall Geheilter Zahnfractur." *Virchow's Archiv*, 1867.

a left upper central, was extracted from a girl eighteen years of age, who about eight years previously had a fall, after which the tooth changed its position and became painful. Microscopical examination revealed the peculiar fact that, in consequence of the injury,—the direction of the fracture being probably the fissure seen in Fig. 324 on the left upper periphery of the crown, —a marked new formation of enamel (*ER*) took place. A second remarkable feature is the formation of several vascular canals (*V*, *V*) in the dentine, around which the canaliculi take a fan-like course. Inexplicable is the fact that at the apex of the root, between two layers of cementum, a layer of dentine had formed. (See Fig. 324.)

FIG. 325.



RIGHT UPPER LATERAL INCISOR IN A HORIZONTAL POSITION. NATURAL SIZE. (From Wedl.) *A*, edge of the tooth protruding on the surface; *G*, imperfect lateral temporary incisor; *C*, empty alveoli.

XII. Malpositions of the Teeth are quite frequent, and too variable to be enumerated in any particular way. As many excellent works have been written on this subject, I refer those who take special interest in this topic to the books of John and Charles S. Tomes, Baume, Farrar, Kingsley, and Talbot.

In rare cases teeth, usually fully developed, are found in the antrum, in the nasal cavities, and under the skin on almost any part of the face.

In conclusion, I wish to mention that several cases of absolute absence of both temporary and permanent teeth are on record in the literature, so-called "edentuli."

LITERATURE.

The author is sensible that the references to the literature of the subjects treated in this book are incomplete, but he nevertheless cherishes the hope that his earnest efforts have added real value to the catalogue of authors who have contributed to the general stock of knowledge in this direction, and that the labors of those who delve in the same field after him will thus be lightened.

To avoid frequent repetitions the standard works are given first, as bearing more or less on every chapter of this work. The remainder of the literature has been arranged as nearly as possible in the order of the chapters, having been collected from the principal American, English, and German journals, as well as from the works of Miller, Arkövy, and Scheff.

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